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Performance Measure Datasheets

Delta Plan Amendments

May 2020

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Performance Measure 4.6: Doubling Goal for Central Valley Chinook Salmon Natural Production

Performance Measure (PM) Component Attributes

Type: Outcome Performance Measure

Description

Increase in Central Valley Chinook salmon population recovery with natural production to reach the state and federal doubling goal.

Expectations

The annual average natural production of Central Valley Chinook salmon runs increases long-term to double the 1967–1991 levels for all runs combined, and for individual run types on select rivers: fall, late-fall, spring, and winter.

Metric

Annual average natural production of all Central Valley Chinook salmon runs and for individual run types on select rivers: fall, late-fall, spring, and winter. Census will be conducted annually for the general population in the Central Valley and select rivers.

Baseline

Set by the Central Valley Project Improvement Act (CVPIA), the baseline is the 1967–1991 Chinook salmon natural production annual average of 497,054 for all Central Valley runs (Figure 1), and for individual run types on select rivers, the baseline values are specified in Table 1.[1]

[1] The baseline values in Table 1 do not add up to the baseline for all runs because not all tributaries are included. The Council will only track individual run types for the select rivers specified in Table 1.

Targets

The 15-year rolling annual average of natural production for all Central Valley Chinook salmon runs increases for the period of 2035–2065, and reaches 990,000 fish by 2065, and for each run on select rivers, the target values are specified in Table 1.[2]

Table 1. Central Valley Chinook Salmon Natural Production Baseline and Target Levels by Run Type and Selected Rivers

Baseline (1967–1991)		Target (2065)	
Sacramento River Watershed	San Joaquin River Watershed	Sacramento River Watershed	San Joaquin River Watershed
Sacramento River mainstem Fall: 115,369 Late-Fall: 33,941 Spring: 29,412 Winter: 54,316	Tuolumne River Fall: 18,949	Sacramento River mainstem Fall: 230,000 Late-Fall: 68,000 Spring: 59,000 Winter: 110,000	Tuolumne River Fall: 38,000
American River Fall: 80,874	Merced River Fall: 9,005	American River Fall: 160,000	Merced River Fall: 18,000
Feather River Fall: 86,028	Stanislaus River Fall: 10,868	Feather River Fall: 170,000	Stanislaus River Fall: 22,000
	Mokelumne River Fall: 4,680		Mokelumne River Fall: 9,300

Basis for Selection

Enacted by the U.S. Congress in 1992, the Central Valley Project Improvement Act (CVPIA) requires improvements to water management to protect fish and wildlife, including achieving the state and federal doubling goal for Central Valley Chinook salmon natural production, relative to 1967–1991 levels. U.S. Fish and Wildlife Service (1995) defines natural production as: "Title 34 defines natural production as: '... fish produced to adulthood without direct human intervention in the spawning, rearing, or migration processes' (Section 3403[h])." Although the CVPIA spurred much action and changes to water management, extensive drought periods have contributed to decreased salmon natural production levels since 1992: the 1992–2015 average was 381,368 compared to the 1967–1991 baseline average of 497,054 (Figure 1) for all Chinook salmon runs. Given the importance of this species for commercial and recreational fishing, and its cultural value, there is considerable interest in tracking its status. Moreover, salmon are a strong indicator species of ecosystem health and of the effectiveness of habitat restoration and water-quality improvement projects because

[2] The targets in Table 1 do not add up to the target for all runs because not all tributaries are included. The Council will only track individual run types for the select rivers specified in Table 1.

these anadromous fish use the vast range of aquatic ecosystems, from headwaters to the ocean (NMFS 2014). Salmon also play an important ecological role during their migration upstream to spawn by transferring nutrients from the ocean to wildlife and vegetation in the Central Valley (Merz and Moyle 2006). They are a critical food resource for terrestrial predators and scavengers, connecting ocean and forest habitats hundreds of miles apart (Wilson et al. 1998). Therefore, declines in the capacity of a watershed to support all stages of salmon can indicate declining ecosystem health (Cummins et al. 2008).

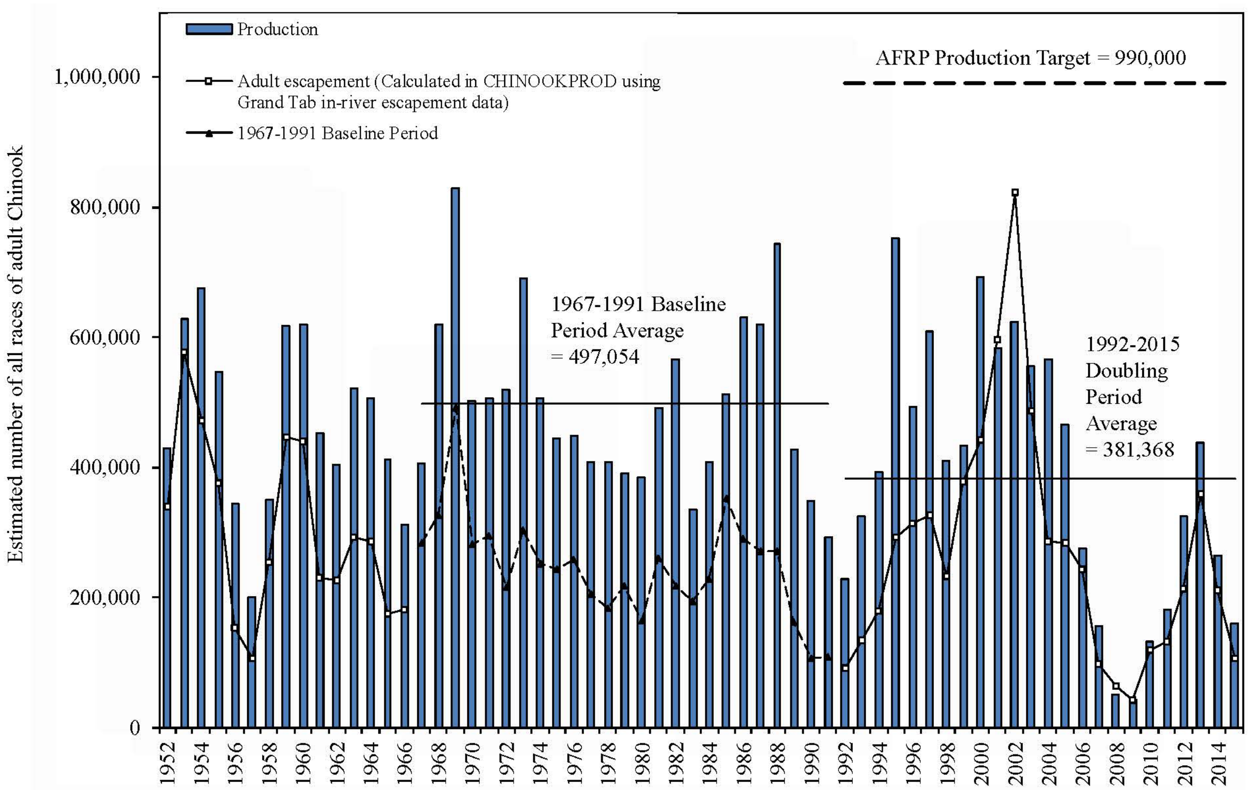

Figure 1. Estimated Yearly Natural Production and In-River Escapement of all Races of Adult Chinook Salmon in the Central Valley Rivers and Streams

This chart illustrates the estimated annual natural production and in-river escapement of all races of adult Chinook salmon in the Central Valley rivers and streams. Chinook salmon escapement is defined as fish that migrate from the ocean to spawn in freshwater streams. The x-axis shows time, starting from 1952 through 2014 in two-year increments. The y-axis shows the estimated number of all races of adult Chinook, ranging from 0 to 1,000,000, in increments of 200,000. Vertical bars represent annual production of all races of Chinook, while a line graph represents the annual adult escapement. The escapement estimates were calculated in ChinookProd using Grand Tab in-river escapement data.

Figure 1. Estimated Yearly Natural Production and In-River Escapement of all Races of Adult Chinook Salmon in the Central Valley Rivers and Streams (contd.)

The chart shows that both production and adult escapement are variable, but that they tend to increase and decrease together. Production and escapement both rose by roughly 200,000 adult Chinook between 1952 and 1953. Production increased the following year, while escapement dropped slightly. Both production and escapement fell in the subsequent three years, to a regional low in 1956 of roughly 200,000 adult Chinook produced and roughly 100,000 escaped. Production and escapement both rose over the next two years, and then varied in concert with one another, peaking in 1969 at more than 800,000 produced and 500,000 escaped. In 1992, production and escapement hit a regional low at less than 250,000 adult Chinook produced and roughly 100,000 escaped. Between 1992 and 2002, both production and escapement generally increased. Production hit a regional peak of more than 750,000 in 1995 and escapement peaked in 2002 at more than 800,000 adult Chinook. Both production and escapement then declined to a low of roughly 50,000 Chinook produced and escaped in 2009. Production and escapement increased between 2009 and 2013 to a regional high of roughly 450,000 produced and 350,000 escaped, then dropped over the next two years.

The central message of the chart is conveyed through comparison of a baseline period average, a doubling period average, and a production target. The chart shows that the 1967–1991 baseline period average equals 497,054 adult Chinook. The chart shows the 1992–2015 doubling period average equals 381,368. The target for the doubling period was 990,000 fish. The chart illustrates that the 1992–2015 average falls well below the target.

Source: USFWS Anadromous Fish Restoration Program 2016

Salmon populations are dependent on a wide variety of factors in the rivers, Delta, and ocean, including suitability of spawning and rearing habitat, predation, and food availability (USFWS and Reclamation 2011). They can be sensitive to changes in water quality, flow, turbidity, and temperature. Moreover, stressors affect various salmon life stages differently (NMFS 2014). Degrading conditions in recent decades have caused major declines in Central Valley Chinook salmon populations, resulting in listing of winter-run Chinook salmon as an endangered species and spring-run Chinook salmon as a threatened species under the federal Endangered Species Act.

Salmon population dynamics are dependent on many factors that occur outside the Delta (e.g., spawning habitat, water temperatures) that can be managed through flow and nonflow management actions such as water operations, fishing regulations, habitat restoration, as well as other factors that cannot be managed (e.g., ocean food-web productivity). Management of water operations, habitat restoration, and increased coordination among agencies in the Delta can help contribute towards the salmon doubling goal (Cummins et al. 2008, Herbold et al. 2018, Dahm et al. 2019). Current ecosystem management seeks to improve the adaptive capacity of salmon in response to climate change by reconnecting and restoring habitats to facilitate ecosystem processes, providing refuge from temperature stress and predation risk, and by increasing food availability (Crozier et al. 2019).

In 2018, the State Water Resources Control Board (SWRCB) charged an Independent Scientific Advisory Panel with developing methods for formulating biological goals for the Bay-Delta Water Quality Control Plan. The Advisory Panel concluded that the baseline for the doubling goal overestimated the natural-origin population (by underestimating hatchery-origin Chinook salmon in total returns) and therefore the doubling goal for natural-origin salmon might also be overestimated (Dahm et al. 2019). Because of the uncertainty in the baseline calculations, an increase in the natural production (positive trend) may provide a better goal, rather than the goal to double the natural production (Dahm et al. 2019). Since 2007, the Constant Fractional Marking program conducted by CDFW has helped increase the accuracy of fall-run natural production estimates. Therefore, in addition to the main doubling goal target, there will be two submetrics that address the limitations of the current datasets and compliments the overall intentions of the doubling goal.

These submetrics are: 1) an increase in natural-origin population as a positive slope of the 15-year rolling annual average for the period of 2035–2065; 2) a positive slope of the 15-year rolling annual average of natural production using CFM data from 2010–2065. These values will be calculated for each tributary and Chinook run listed in the targets section (above).

Linkages to Delta Reform Act and the Coequal Goals

Delta Reform Act

Achieving the target of positive slope in the 15-year annual average of natural production for all Chinook salmon is a measure of “Conditions conducive to meeting or exceeding the goals in existing species recovery plans and state and federal goals with respect to doubling salmon populations” (Water Code section 85802(c)(5)).

This performance measure works together with other performance measures—Fish Migration Barriers (PM 4.13), Increase Seasonal Inundation (PM 4.15), Acres of Natural Communities Restored (PM 4.16), and Subsidence Reversal for Tidal Reconnection (PM 4.12)—to assess the status and trends in “the health of the Delta’s estuary and wetland ecosystem for supporting viable populations of Delta fisheries and other aquatic organisms” (Water Code section 85211(a)).

Delta Plan Core Strategy

4.4 Protect Native Species and Reduce Impact of Nonnative Invasive Species.

Methods

Baseline Methods

The baseline is the average number of annual natural production of all Central Valley Chinook from 1967–1991 which is 497,054 fishes. This was set by the Central Valley Project Improvement Act (CVPIA) of Public Law 102-575, passed by Congress in 1992.

Target Methods

The target is doubling the baseline to 990,000 by 2065, expressed as the 15-year rolling annual average of natural production for all Chinook salmon runs. The 15-year rolling average represents the time frame for about five salmon generations and is intended to account for short-term variability of salmon production.

Data Sources

Primary Data Sources

The primary data sources listed below will be used for tracking this performance measure:

1. U.S. Fish and Wildlife Service (USFWS) ChinookProd. Assesses progress toward the CVPIA doubling goal for natural production. These data are based upon California Department of Fish and Wildlife (CDFW) Grand Tab data. Estimates of adult salmon are based on counts entering hatcheries and migrating past dams, carcass surveys, live fish counts, and ground and aerial redd counts.
    a. Content: ChinookProd is a spreadsheet database maintained by the USFWS Anadromous Fish Restoration Program, which calculates natural production of each salmon run along with the combined value of all runs (Figure 1). ChinookProd is both a data source and an analytical tool.
    b. Update frequency: Updated annually.
2. CDFW Grand Tab. Provides estimates of adult salmon escapement (returning spawners) for different run types and watersheds. Estimates are provided by the CDFW; USFWS; California Department of Water Resources; East Bay Municipal Utilities District, U.S. Department of the Interior, Bureau of Reclamation (Reclamation); Lower Yuba River Management Team; and Fisheries Foundation of California. Grand Tab does not characterize whether fish are wild or hatchery origin, just whether the adults are spawning in-river (natural) or in-hatchery.

Escapement data and visualizations are available through the Central Valley Prediction and Assessment of Salmon website (SacPAS).

a. Content: Tabular reports of salmon escapements by salmon run and rivers.

b. Update frequency: Updated annually.

Alternative Data Sources

Alternative data sources will be used if the primary data sources become unavailable or insufficient. Alternative data sources may be used concurrently with the primary data sources depending on best available science and the availability of the primary source.

1. CDFW Constant Fractional Marking.https://www.fws.gov/cno/fisheries/CAMP/Documents-Reports/CDFW Constant Fractional Marking. Until 2007, only experimental releases of hatchery fall-run Chinook salmon were marked and tagged, resulting in lack of data on hatchery impacts on natural production. Since 2007, the constant fractional marking (CFM) program coded-wire tagging and adipose fin-clipping of at least 25 percent of all CV hatchery Chinook salmon. Each CWT contains a binary or alpha-numeric code that identifies a specific release group of salmon (e.g., agency, species, run, brood year, hatchery or wild stock, release size, release date(s), release location(s), number tagged and untagged). CFM provides a more accurate estimate of the relative contribution of hatchery fish to total natural production.
    a. Content: Tabular reports of salmon escapements by salmon run and rivers.
    b. Update frequency: Updated annually
2. USFWS Comprehensive Assessment and Monitoring Program Annual Report. USFWS Comprehensive Assessment and Monitoring Program Annual Report.
    a. Content: Annual report that provides updates on progress of the Anadromous Fish Restoration Program and the salmon doubling goal.
    b. Update frequency: Updated annually.

Process

Data Collection and Analysis

Every year, Council staff will update the status of this performance measure by:

a. Downloading data from primary data source #1 every October 1. Council staff will contact the data owner, USFWS, for quality assurance-quality control questions, if necessary.
b. Calculating the 15-year rolling annual average of natural production for all Chinook salmon runs.
c. Calculating the slope (linear regression) of 15-year rolling annual averages of natural production for all Chinook salmon runs.
d. Displaying results such as bar graphs (e.g., Figure 1) showing the rolling annual natural production of all salmon runs and the status, compared to the baseline. The 15-year rolling averages will be plotted against year and a slope will be calculated to measure if the salmon population is growing (positive slope).

Interim Performance Assessment

In order to provide a short-term assessment of progress toward the doubling target, and to address limitations of the current datasets, interim milestones are set using two submetrics:

1. Positive slope of the 15-year rolling annual average of Central Valley Chinook salmon natural production, calculated and evaluated annually. The interim milestone is a positive slope of the 15-year rolling annual average to be achieved by 2035.
2. Positive slope of the 15-year rolling annual average of natural production using the Constant Fractional Marking (CFM) data which is available from 2010 onwards. The interim milestone is a positive slope of the 15-year rolling annual average by 2035.

Annually, the linear regression and associated slope for the regression line will be calculated and compared to the baseline and to the previous year values. The 15-year rolling average was chosen to represent five Chinook salmon generations to provide long enough trends to conclude whether populations are in recovery or not (USFWS 1995).

The interim metrics are calculated by each run and by selected rivers where production data is available. Interpretation of short-term performance milestones assessments will include consideration of external factors beyond management control (e.g., ocean and climate conditions) and the relative importance of the Delta as the migration corridor and rearing habitat within the salmon life cycle.

Process Risks and Uncertainties

Current monitoring efforts do not adequately characterize whether fish are wild or of hatchery-origin. Consistently and comprehensively estimating the contribution of hatchery-origin salmonids in the catch and spawning grounds is the greatest deterrent to reasonably accurate production estimates of natural-origin salmonids (Dahm et al. 2019).

The USFWS ChinookProd estimates of annual natural production of each Chinook salmon run from each watershed includes four components:

1. In-river spawner abundance (i.e., escapement): In-river spawner abundance is based on the CDFW Grand Tab report. If there is a salmon hatchery in a watershed, hatchery returns are quantified by counting the number of salmon that enter those fish hatcheries. In-river harvest is estimated using best professional judgment based on CDFW angler harvest surveys.
2. Hatchery returns.
3. In-river harvest by anglers.
4. Ocean harvest is based on reporting by the Pacific Fishery Management Council.

Climate change poses another uncertainty to reaching salmon doubling targets. To help address this, Council staff will work with SWRCB and other agencies to track abundance as well as density-dependence survival rates, distribution, diversity, and life stage survival rates of Central Valley salmon in order to better adaptively manage their populations. Moreover, there is a need to investigate how these population parameters are affected by management actions.

Reporting

Every year, Council staff will report the status of this performance measure by:

1. Posting updates on the Performance Measures Dashboard.
2. Providing results in the Council's annual report (published in January).
3. Communicating management-relevant results at Council and Delta Plan Interagency Implementation Committee (DPIIC) public meetings.
4. Presenting findings at technical interagency groups, professional gatherings, and conferences.

Every five years, Council staff will assess and report the status of this performance measure by:

1. Communicating findings in the five-year review of the Delta Plan.
2. Informing the Council's adaptive management process, and other decision-making.

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Performance Measure 4.12: Subsidence Reversal for Tidal Reconnection

Performance Measure (PM) Component Attributes

Type: Output Performance Measure

Description

Subsidence reversal[1] activities are located at shallow subtidal elevations to prevent net loss of future opportunities to restore intertidal wetlands through tidal reconnection in the Delta and Suisun Marsh.

Expectations

Preventing long-term net loss of land at intertidal elevations in the Delta and Suisun Marsh from impacts of sea level rise and land subsidence.

Metric

1. Acres of Delta and Suisun Marsh land with subsidence reversal activity located on islands with large areas at shallow subtidal elevations. This metric will be reported annually.
2. Average elevation accretion at each project site presented in centimeters per year. This metric will be reported every five years. Tracking will continue until a project is tidally reconnected.

Baseline

1. In 2019, zero acres of subsidence reversal on islands with large areas at shallow subtidal elevations.
2. Soils in the Delta are subsiding at a rate of between 0 cm/year and 1.8 cm/year.

[1] Subsidence reversal is a process that halts soil oxidation and accumulates new soil material in order to increase land elevations. Examples of subsidence reversal activities are rice cultivation, managed wetlands, and tidal marsh restoration.

Target

1. By 2030, 3,500 acres in the Delta and 3,000 acres in Suisun Marsh with subsidence reversal activities on islands with at least 50 percent of the area or at least 1,235 acres at shallow subtidal elevations.
2. For each project, an average elevation accretion of at least 4 centimeters per year until the project is tidally reconnected.

Basis for Selection

General Purpose

California will experience sea level rise over the next century. The Ocean Protection Council's guidance estimates that sea level rise at San Francisco Bay, the nearest forecasted area to the Delta, could range from an increase of 1.6 feet to 10.2 feet by 2100 (OPC 2018). Anticipated sea level rise will increase pressure on already stressed Delta ecosystems (Council 2018). In addition to sea level rise, most of the land in the Delta is subsiding due to microbial oxidation and areas in the central Delta are already below sea level (Deverel et al. 2016). The areas at subtidal elevations offer limited ecological value if reconnected to a stream because species native to the Delta are not well adapted to lake-like deep water habitats (Durand 2017). Only a thin band of land is at appropriate elevations suitable for tidal restoration through hydrologic reconnection (Delta Plan, Appendix Q2) and that band is getting smaller as the landscape subsides and sea level rises. Hence, the potential for future tidal restoration is being lost.

Many of the existing areas suitable for tidal wetland restoration are already being targeted for restoration as part of the California EcoRestore initiative.[2] Finding additional areas suitable for tidal wetland restoration will become increasingly difficult. Many of the most suitable areas already have tidal wetland restoration projects planned, and other areas in the Delta are becoming incapable of supporting intertidal restoration due to sea level rise and subsidence. One way to preserve the potential for future intertidal restoration on the landscape is through subsidence reversal.

If subsidence reversal activities are located at suitable locations, the accumulated land can counteract effects of sea level rise and historic subsidence, and maintain or increase land elevation. Recovering lost land will also preserve the opportunities for tidal reconnection. Subsidence reversal activities in locations with current shallow subtidal elevations could recover land for tidal restoration and prevent further losses

[2] California EcoRestore is a California Natural Resources Agency initiative (http://resources.ca.gov/ecorestore).

from sea level rise. To recover tidal restoration opportunities, islands identified in this performance measure should initiate subsidence reversal projects by at least 2030, and then continue long-term until the land reaches the desired intertidal elevation—becoming available for tidal reconnection and subsequent tidal wetland restoration.

The Council's landscape model (see Methods section below) indicates that from 2008 to 2019 (the decade following the passage of the Delta Reform Act of 2009), the Delta and Suisun Marsh lost 3,500 acres and 3,000 acres of land, respectively, at intertidal elevations due to subsidence and sea level rise. By initiating subsidence reversal activities on 3,500 Delta acres and 3,000 acres in Suisun Marsh, land that was once at intertidal elevations can be recovered, and subsequently, maintaining opportunities for future tidal reconnection and restoration. In order to accrete sufficient elevation at the identified locations, projects would need to accrete at least 4 centimeters per year.

Subsidence reversal is a process that increases land elevation by halting soil oxidation and accumulating new soil material. Subsidence reversal activities are conservation actions that can be implemented as multibenefit projects that support native species and natural communities. Subsidence reversal projects that are managed wetlands can provide habitat for migratory bird species (Shuford and Dybala 2017, Shuford et al. 2019) and support native vegetation communities. After suitable land elevation is reached, locations can become available for tidal reconnection and tidal wetland restoration that in turn benefits aquatic species and native fish populations, while restoring natural geomorphic processes.

Relationship to the Subsidence Reversal and Carbon Sequestration Performance Measure (PM 5.2)

Delta Plan performance measure PM 5.2, "Subsidence Reversal and Carbon Sequestration," tracks carbon sequestration projects and acres of subsidence reversal projects across the entire Delta and Suisun Marsh. PM 5.2 has a target of 30,000 acres of subsidence reversal and carbon sequestration in the Delta to be achieved by 2030. Managed wetlands or rice production on deeply subsided areas operated for subsidence reversal sequester carbon in the organic material they accrete. This decreases carbon emissions for organic soils. Subsidence reversal projects to sequester carbon can take advantage of carbon credit markets while also helping California meet its greenhouse gas reduction targets. Shallow subsided areas (shallow subtidal elevations) tend to not emit high amounts of carbon dioxide compared to the deeply subsided areas, therefore, it is unlikely that carbon markets will incentivize projects in these areas.

This performance measure PM 4.12, "Subsidence Reversal for Tidal Reconnection" is different from PM 5.2 because it only tracks subsidence reversal located on islands with shallow subtidal elevations, whereas PM 5.2 tracks both shallow and deeply subsided areas. Shallow subtidal elevations have a reasonable chance of achieving intertidal elevations through subsidence reversal in the timeframe from 2020 to about 2100, preventing the net loss of future opportunities to restore tidal wetlands. Deeply subsided areas may need more than 80 years to be restored to intertidal elevations making such projects unlikely to result in intertidal habitat within a planning horizon of 2100.

Relationship to the Performance Measure Acres of Natural Communities Restored Performance Measure (PM 4.16)

The performance measure PM 4.16, "Acres of Natural Communities Restored Performance Measure" targets the creation of 32,500 acres of tidal wetlands. Actions that support the landscape potential for tidal wetland restoration will also support the achievement of that target. If the target is achieved, this performance measure would result in 6,500 acres of wetlands tidally reconnected to the system in Suisun Marsh and the Delta. The 6,500 acres suitable for tidal restoration that would result from successful achievement of this performance measure (PM 4.12) target would account for 20 percent of the PM 4.16 target acreage. However, depending on the location and subsidence rates, some of the acreage tracked by this performance measure may not be suitable for reconnection by the 2050 target of PM 4.16.

Linkages to Delta Reform Act and the Coequal Goals

Delta Reform Act

The loss of land elevation is a major stressor on the ecosystem that makes restoration of the Delta more difficult. The Sacramento-San Joaquin Delta Reform Act of 2009 (Delta Reform Act) defines a number of strategies for restoring a healthy Delta ecosystem. Achieving the target in this performance measure would support the following subgoals and strategies for restoring a healthy ecosystem:

- **"Restore large areas of interconnected habitats within the Delta and its watershed by 2100." (Water Code section 85302(e)(1)).** Due to sea level rise and subsidence on land at current intertidal elevation, the potential for habitat reconnection is being lost. In the 10-year period (2009 to 2019) of modeled elevation change (see methods section below), 3,500 acres are estimated to have been lost in the Delta and 3,000 acres in Suisun Marsh since the passage of the Delta Reform Act. Applying subsidence reversal activities on the same amount of land will prevent the net loss of opportunities to restore tidal wetlands due to subsidence and sea level rise.

- **"Restore Delta flows and channels to support a healthy estuary and other ecosystems." (Water Code section 85302(e)(4)).** Delta geometry has been radically simplified from the complex channel systems that were common in the pre-reclamation Delta (SFEI-ASC 2016). With large-scale wetland restoration, the formation of complex dendritic channels is possible. This measure tracks projects that could create new spaces for restoring those geomorphic formations. Those new spaces would offset the loss of elevation occurring elsewhere.
- **"Restore habitat necessary to avoid a net loss of migratory bird habitat and, where feasible, increase migratory bird habitat to promote viable populations of migratory birds."** (Water Code § 85302(e)(6)). Both managed wetlands—for subsidence reversal in deeply subsided and shallow subsided areas—provide habitat for migratory bird species (Shuford and Dybala 2017, Shuford et al. 2019).

In addition to providing subgoals and strategies for restoring a healthy Delta ecosystem, the Delta Reform Act also mandates that the Delta Plan include measures that promote specified characteristics of a healthy Delta ecosystem (Water Code section 85302(c)). Achieving the target in this performance measure would promote the following characteristics of a healthy Delta, as identified in the Delta Reform Act:

- **"Viable populations of native resident and migratory species." (Water Code section 85302(c)(1)).** Prior to reclamation, native and migratory species thrived in a dynamically inundated tidal marsh system (SFEI-ASC 2016). In the last 150 years, more than 95 percent of wetlands in the Delta have been lost; those wetlands were habitat for many native species (SFEI-ASC 2016). Without opportunities on the landscape to restore lost tidal wetlands, it will be difficult to support viable populations of native resident and migratory species. PM 4.16, "Natural Communities Restored," sets targets for the number of acres of natural wetlands to be restored. Achieving that goal will require significant space on the landscape. Meeting the target of this measure will ensure that the Delta landscape maintains opportunities for natural wetland restoration, as opposed to losing suitable landscapes due to sea level rise and subsidence.
- **"Diverse and biologically appropriate habitats and ecosystem processes." (Water Code section 85302(c)(3)).** The pre-reclamation Delta was characterized by a diverse series of seasonally inundated tidal wetlands that provided complex and variable hydrology and landscape patterns (SFEI-ASC 2016). Restoring these processes will require space on the landscape that is not deeply subtidal. The intertidal space is being lost to subsidence and sea level rise. Meeting the target of this measure will ensure that the Delta landscape recovers opportunities to restore seasonally inundated tidal wetlands and fluvial and geomorphic patterns.

- **"Reduced threats and stresses on the Delta ecosystem." (Water Code section 85302(c)(4)).** Land loss is a stress on the ecosystem. Deeply subsided islands offer less potential habitat value than those of intertidal elevations (Durand 2017). Meeting the target of this measure will ensure no net loss of the land at intertidal elevation.
- **"Conditions conducive to meeting or exceeding the goals in existing species recovery plans, and state and federal goals with respect to doubling salmon populations."** (Water Code section 85302(c)(5)). Loss of land at intertidal elevations prohibits opportunities for restoring large areas of tidally connected wetlands that support native fish species and the doubling of salmon populations. Meeting the target of this measure will ensure that the Delta landscape maintains opportunities for natural wetland restoration.

Delta Plan Core Strategy

4.3 Protect Land for Restoration and Safeguard Against Land Loss.

Methods

Subsidence Reversal Activity

This performance measure tracks "subsidence reversal activity." Subsidence reversal is a process that both halts subsidence caused by organic soil oxidation and leads to increases in land elevation through accumulation of new soil material. Subsidence reversal results in land elevations that are higher than land elevations prior to subsidence reversal; the process does not necessarily result in land elevations at or above mean sea level, however, because this depends on the initial elevation and the rate of subsidence reversal over time. Examples of subsidence reversal management actions include, but are not limited to, increasing land elevation by accreting organic material in managed wetlands, and placement of fill and levee breaching to reestablish hydrological connection with a river or bay.

For the purposes of this performance measure, subsidence reversal activity is defined as projects that include landscape interventions that increased land elevation in nontidally connected locations whose elevations are below nearby water levels. There are two common forms of subsidence reversal in the Delta. The first form is vegetation-based, in which managed wetlands (Miller et al. 2008), or a rice and wetland mosaic landscape (Deverel et al. 2017) are used to accrete organic material on an area that increases elevation. The other form of subsidence reversal is through the application of sediment on a landscape. For example, prior to tidal reconnection elevations in areas of the Montezuma Wetlands had dredge material deposited on them to raise their elevations. Due to limited availability of dredge spoils and other sediment, this form of subsidence reversal is likely to be less common and more limited in its geographic scope.

Baseline Methods

Islands in the Delta and Suisun Marsh with large enough areas at shallow subtidal elevations were identified as capable of reaching intertidal elevations with subsidence reversal ongoing from 2030 to 2100 (see method below).

The subsidence rates for soils in the Delta of between 0 cm/year and 1.8 cm/year are based on soil composition models from subsidence rates (Deverel et al. 2016).

Target Methods

Acres of Intertidal Land Lost Since the Delta Reform Act

Areas at current intertidal elevation were derived from the Delta and Suisun Marsh 2007-2008 digital elevation model (DEM) and 2017 DEM revisions by the Department of Water Resources (DWR) (Tolentino 2017). Because the DEM was produced based on (mostly) conditions on the ground in 2008 (Tolentino 2017), the baseline is 2008 and the analysis tracks intertidal elevation loss of the following ten years. The estimated intertidal land loss is calculated for 10 years of elevation change based on the projected subsidence and sea level rise (method described in Appendix 1). The resulting 3,500 Delta acres and 3,000 acres in Suisun Marsh is the estimated area of land lost following the passage of the Delta Reform Act.

The land loss is calculated for ten years based on the Tolentino (2017) DEM, most of which is based on 2008 LiDAR survey, because at the time of development of the model it was the best available data. Projected sea level rise and subsidence indicate that more intertidal land could be lost if action is not taken.

Implementation by 2030

The target date for project implementation is for 2030 because rates of sea level rise and subsidence reversal have a high uncertainty. A longer-term target date requires more foreknowledge of sea level rise and the future development of subsidence reversal technology. Subsidence reversal technology in the Delta is in the early stages of development. Currently, there are only a few subsidence reversal projects in the Delta and none in Suisun Marsh. By 2030, more subsidence reversal projects are expected to be implemented and evaluated, contributing to the state of the science and the adaptive management. The 2030 target date is consistent with the existing performance measure PM 5.2, “Subsidence Reversal and Carbon Sequestration.”

Identifying Islands with Large Areas of Land Capable of Reaching Intertidal Elevations Suitable for Potential Future Restoration by 2100

The Delta and Suisun Marsh islands were analyzed by Council staff to determine which islands contain significant opportunities to achieve intertidal elevations (needed for tidal reconnection and tidal wetland restoration) through soil accretion from subsidence reversal (technical details are described in Appendix 1). For each island in the Delta and Suisun Marsh, Council staff estimated the amount of vertical soil accretion that could potentially be gained through subsidence reversal based on empirical data from existing subsidence reversal projects. Staff then used GIS to count, for each island, the number of acres that could reach intertidal elevations by 2100 or sooner.

Staff reviewed the elevations at each island and included any island with at least 50 percent of its area or at least 1,235 acres at current shallow subtidal elevations as being able to reach intertidal elevations by 2100 with subsidence reversal and therefore provide future opportunities for tidal reconnection. The 1,235-acre threshold was selected because it is the minimum area needed for complex intertidal channel systems to develop in a wetland complex (SFEI-ASC 2016) and would therefore allow for large-scale intertidal wetland restoration. This 1,235-acre threshold is also used in Delta Plan, Appendix Q2 to determine if a tidal wetland project is large-scale. An island list (Appendix 2) and map (Figure 1) were manually corrected to exclude islands that included large acreage but little connectivity to support channel formation such as Brannan-Andrus Island.

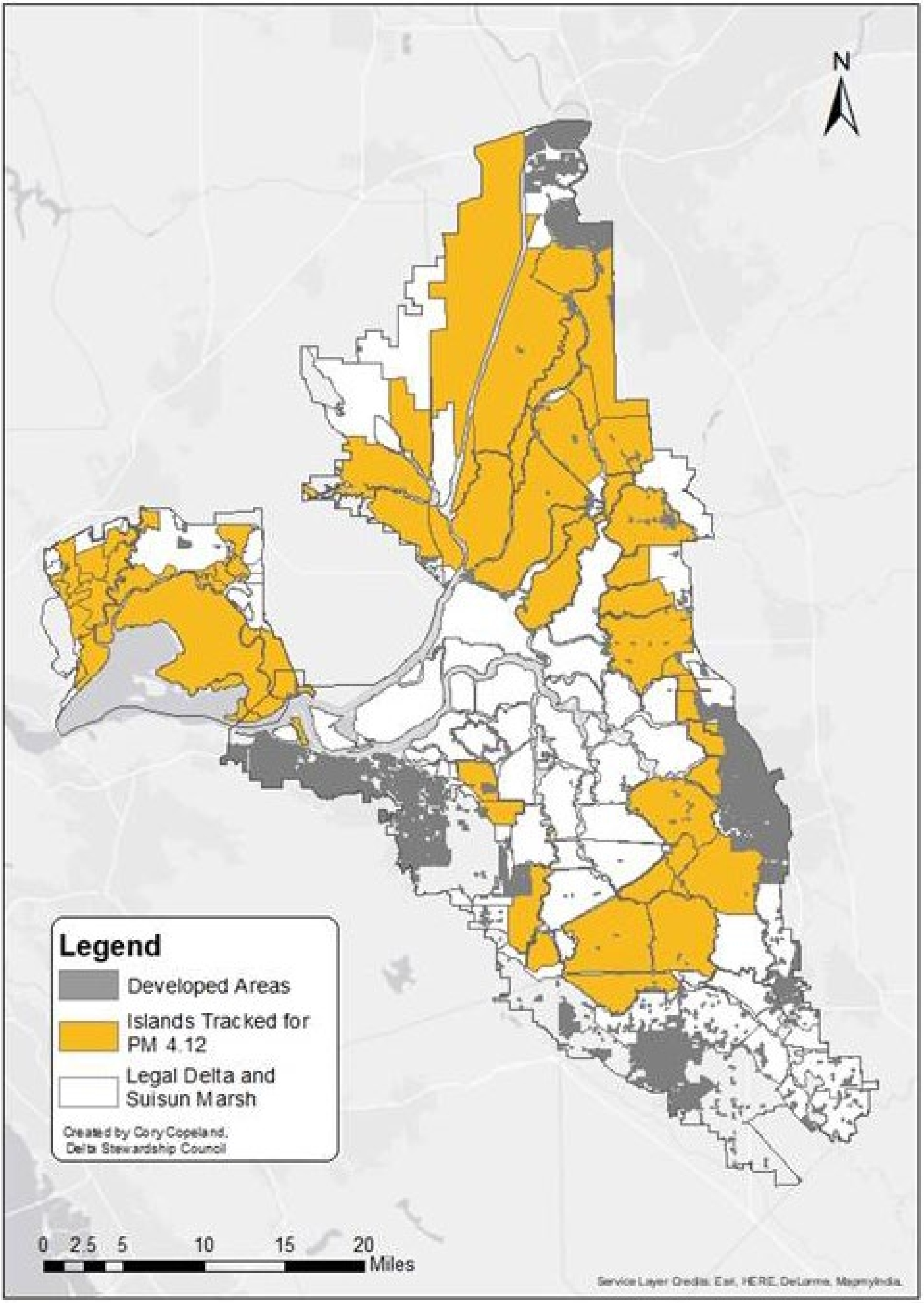

Figure 1. Islands Tracked in this Performance Measure

Figure 1. Islands Tracked in this Performance Measure (contd.)

This map shows the areas where subsidence reversal activities ongoing through 2100 can produce intertidal elevations on or before 2100.

Islands that are tracked for this performance measure are concentrated in Suisun Marsh, Cache Slough, Yolo Bypass, the north Delta along the Sacramento River, the eastern Delta near the Cosumnes/Mokelumne confluence, adjacent to the City of Stockton, and in the south Delta north of Tracy and Lathrop. Islands that are not tracked for this performance measure are concentrated in the central Delta where land is too deeply subsided to be reconnected to tidal inundation; and at the edges of the Delta and Suisun Marsh, where land is above the tidal range. The names of the individual islands that are tracked for this performance measure are listed in Appendix 2 of this document.

Alternative formats of this map are available upon request.

Accretion Metric and Target Selection

This measure identifies that projects would need to accrete at least 4 centimeters per year (cm/yr) over a long-term project life. The rate of 4 cm/yr has been shown to be possible over the short-term in the Delta based on empirical data from Twitchell Island (Miller et al. 2008). Subsidence reversal activities must continue to accrete elevation at an average 4 cm/yr rate to reach intertidal elevations suitable for tidal reconnection and tidal wetland by 2100.

Data Sources

Primary Data Sources

The listed primary data sources below will be used for tracking this performance measure. If subsidence reversal project-implementers choose to report project information outside of these listed sources, Council staff will seek to identify additional sources of project information.

1. The Delta Stewardship Council Covered Actions website. Subsidence reversal projects are likely to meet the definition of a covered action and will need to establish consistency with the Delta Plan before implementation.
    a. Content: Covered actions project description provides details about types of subsidence reversal activities, acreages, and locations.
    b. Update frequency: As covered actions are submitted.
2. San Francisco Estuary Institute (SFEI) Project Tracker. The SFEI project tracker is a tool that supports regional tracking of restoration projects. Restoration

projects, including subsidence reversal projects created for the purpose of future intertidal reconnection are anticipated to be tracked on Project Tracker.

   a. Content: Project monitoring region wide.
   b. Update frequency: As projects are implemented.

3. DWR. This agency has the lead role in implementing subsidence reversal projects through the West Delta Program. Initially data will be collected by DWR until other organizations, landowners, and stakeholders begin implementing subsidence reversal projects.
   a. Content: Project specific information.
   b. Update frequency: On a project-by-project basis.
4. CA Wetland Protocol Group. Consists of multiple organizations and/or agencies (e.g., Sacramento-San Joaquin Delta Conservancy (Delta Conservancy), California Department of Fish and Wildlife (CDFW), Sacramento Municipal Utilities District (SMUD), Metropolitan Water District of Southern California (MWD), and the California Coastal Conservancy).
   a. Content: Project specific information.
   b. Update frequency: Variable.
5. California Department of Fish and Wildlife Wetlands Restoration for Greenhouse Gas Reduction Program. Uses Cap-and-Trade money to fund greenhouse gas reduction of emissions. Delta wetlands are a potential future target for this program.
   a. Content: Project specific information.
   b. Update frequency: Based on funding cycles, usually annual or shorter.
6. AmeriFlux Network. U.S. Department of Energy initiative. A network of monitoring stations measuring ecosystem CO2, water, and energy fluxes in North, Central, and South America. For example, the Twitchell Wetland (Twitchell Island East End Habitat Restoration Project) project has a page that includes project-related publications.
   a. Content: Project and related research information.
   b. Update frequency: Variable.
7. San Francisco Bay and Sacramento-San Joaquin Delta Digital Elevation Model (DEM). U.S. Geological Survey DEM is developed based on synthesizing LiDAR, single- and multi-beam sonar soundings, and existing integrated maps collated from multiple sources. It is possible to calculate site-specific changes in land elevation from revisions and updates to DEM.

   a. Content: Elevation data.
   b. Update frequency: About every 10 years.

Alternative Data Sources

Alternative data sources will be used if the primary data sources become unavailable or are insufficient. Alternative data sources can be used concurrently with the primary data sources as a reference or as supplemental information. For this performance measure, the alternative data sources focus on subsidence reversal project implementation that could technically occur independent of the state interests described above, but it is not likely.

1. University of California research programs. UC Berkeley monitors greenhouse gas fluxes on rice and wetlands, and establishes baselines for typical farming practices. UC Davis is researching carbon stock, agronomy effects, and economics of rice management for carbon sequestration.
   a. Content: Research results and published references.
   b. Update frequency: Variable.

Process

Data Collection and Assessment

Every year, Council staff will update the status of this performance measure by:

1. Reviewing the listed primary data sources, and if necessary, contacting the responsible agencies for clarifications on project status.
2. Compiling relevant data and comparing for changes from previous years.
3. Reviewing locations of subsidence reversal projects to assess if they are located on islands listed in this measure (Figure 1 and Appendix 2). Projects on other islands not included in this metric, may be reported under PM 5.2 “Subsidence Reversal and Carbon Sequestration.”
4. Calculating annual acreage of subsidence reversal projects showing a comparison over time and gathering information about vertical elevation changes if available.
5. Displaying project locations on a map.

6. Disclosing alternative or additional data sources used by including them on the Performance Measures Dashboard.

Every five years, Council staff will update the status of this performance measure by:

- Reviewing subsidence reversal project publications, reports, and presentations related to project performance for site-specific accretion rates. Vertical land accretion rates will be reported as a long-term average.
- Reviewing projects to determine if they reached intertidal elevations and have become tidally connected. Once that occurs, staff will no longer track vertical accretion in that project.

Process Risks and Uncertainties

The four major risks related to this measure are the dependence on Delta levees, the sustainability of accretion rates, rates of sea level rise, and timely and comprehensive project reporting. As a part of the Council's adaptive management process, staff will regularly review uncertainties related to the amount of sea level rise, effects of sea level rise, rates of subsidence, subsidence reversal rates, elevations, and project implementation (Table 1).

Delta Levees

Projects below water elevation are dependent on the ongoing maintenance of levees. If a subsided island were to experience levee failures prior to achieving intertidal elevations, and the island was not recovered, it would likely add limited ecological value to native species in the system (Durand 2017). Many islands that may be targets for subsidence reversal are at risk of levee failure (Bates and Lund 2013). While subsidence reversal would decrease the likelihood of levee failures, this remains a persistent risk in the system for subsidence reversal.

Sustainability of Accretion Rates

The identified target of 4 cm/yr of newly accreted elevations is based on a historical statistic. On Twitchell Island, early results for a subsidence reversal project showed that 4 cm/yr was possible (Miller et al. 2008). However, the authors of that report, and subsequent research, indicates that newly accreted organic soils are less dense, and as more soil accretes, the soils compress. This indicates that a long-term accretion rate of 4 cm/yr is unlikely without management adjustments that increase accretion rates; therefore, such adjustments are being explored. Metal-based coagulants sometimes used in wastewater treatment are being explored as a method for capturing more organic material as soil. Early results from a research project in the Delta indicate that applying polyaluminum chloride could increase short-term accretion rates to 6 cm/yr

(Stumpner et al. 2018). The study, however, notes that these new soils are less dense, and may be subject to greater compression, making 6 cm/yr an unlikely long-term vertical accretion rate.

Sea Level Rise

Sea level rise forecasting carries significant uncertainty. The range of sea level rise at San Francisco Bay—recommended for planners to consider by the Ocean Protection Commission—is between 0.49 meters (1.6 feet) and 3.1 meters (10.2 feet) through 2100 (OPC 2018, p. 18). For the landscape model, the median sea level rise projection of 0.76 meters (2.5 feet) was chosen for the high-emission scenario. The Delta, and especially the eastern parts of the Delta where the least-subsided islands are located, is inland from the San Francisco Bay; therefore, likely impacts from sea level rise in the Delta will be experienced at a lower rate. If sea level rise occurs more slowly than the median projection, and affects these areas less than projected, this analysis may have ultimately excluded locations capable of reaching intertidal elevation through subsidence reversal. However, if sea level rise occurs more quickly than projections indicate, the analysis may have included areas unlikely to achieve intertidal elevations given the assumptions of the model.

This uncertainty is managed two ways. The first way is by aggregating the subisland scale analysis of appropriate locations to the island scale. A more rapid rate of sea level rise may lead to a lesser portion of the island reaching intertidal elevations, but unless there is rapid sea level rise much of the island may still be suitable for future intertidal reconnection. The second way this uncertainty is managed is by offering a short-term target with an acreage capable of being accomplished by means of projects.

Project Reporting

For this performance measure, there is no single data source. Instead, tracking these metrics will require Council staff to stay aware of projects implemented in the Delta. These sources will be tracked at least annually on a recurring basis but may be updated more frequently as Council staff become aware of projects. Subsidence reversal projects implemented by a state or local agency in the Delta are likely to be subject to Council’s process for potential covered actions to determine consistency with the Delta Plan. However, Council staff will review the identified sources for information on projects.

Reporting

Every year, Council staff will report the status of this performance measure by:

1. Posting updates on the Performance Measures Dashboard.

2. Providing results in Council's annual report (published in January).
3. Communicating management-relevant results at Council and Delta Plan Interagency Implementation Committee (DPIIC) public meetings.
4. Presenting findings at technical interagency groups, professional gatherings, and conferences.

Every five years, Council staff will assess and report the status of this performance measure by:

1. Communicating findings in the five-year review of the Delta Plan.
2. Informing the Council's adaptive management process and other decision-making.
3. Council staff will evaluate six key uncertainties (shown in Table 1) related to the amount of anticipated sea level rise, the heterogeneity of its effects, and the rates of subsidence in the Delta to determine the trigger for reassessment of targets or metrics for this performance measure.

Table 1. Key Uncertainties for Effectiveness Assessment Review

Key Uncertainty	Assumption Made	Trigger for Reassessment
Amount of sea level rise	2.5 feet of sea level rise	Sea level rise occurs faster or slower than projected
Effects of sea level rise	Uniform effects	Improved information on spatially heterogeneous effects of sea level rise in the Delta and Suisun Marsh
Rates of subsidence	Rates occur based on soil composition consistently over time	Improved models or empirical subsidence data that significantly improves estimates
Subsidence reversal rates	4 centimeters per year	Rates change due to site-specific characteristics or new management technologies.
Elevations	Elevations from Tolentino 2017 DEM	Significant change in understanding of Delta landscape elevations.
Project implementation	Projects implemented soon after the adoption of the ecosystem amendment.	If projects are planned but not implemented soon after the adoption of the ecosystem amendment, the appropriate areas may need to be re-evaluated for new implementation scenarios.

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Appendix 1: Detailed Methods

Past Elevation Change Formula

The formula below is the set of intertidal elevations that meet the condition of being within the difference between current intertidal elevation and intertidal elevation 10 years from now (see Figure 1 for an illustrated explanation of the methods). These methods are applied to a 200 m-cell size raster grid covering the Delta and Suisun Marsh.

IT = (IT1 U IT10) - IT10

The acreage area of ***IT*** is an estimate of the number of acres at intertidal elevations today that will not be intertidal after 10 years.

The intertidal zone for the first year (IT_1) is defined using the following formula:

IT1 = MHHW > E < MLLW

Where ***E*** is elevation based on the Delta and Suisun Marsh DEM (Tolentino 2017) which was aggregated to $200m^2$. The DEM was aggregated due to computational limitation. Running the landscape model for multiple scenarios on the aggregated DEM required large live memory resources that dramatically slowed the processing. The aggregation to $200m^2$ improved processing. It was determined that local conditions at a smaller scale likely would better suited for a site specific analysis conducted by a project proponent rather than a landscape level analysis. The aggregation level of $200m^2$ was chosen because it is discrete enough to be smaller than any reasonable project, but large enough ease any computational bottlenecks.

MLLW is tidal datum for mean lower low water levels.

MHHW is tidal datum for mean higher high water levels.

The intertidal zone (IT_{10}) for the tenth year is defined using the following formula:

IT10 = MHHW > E-∆SLR+∆ES > MLLW

ΔSLR is the expected sea level rise. This analysis assumes a linear sea level rise of 0.76 meters (2.5 feet) feet by 2100, with a predicted Golden Gate sea level rise for 50th percentile in RCP 8.5 emission scenario. Only sea level rise over the next 10 years was taken into account.

ΔES is the change in elevation from subsidence within 10 years. For each pixel in the DEM the rate of change is given by the subsidence rates estimated in Deverel et al. (2016) based on organic soil composition.

The target for acres was calculated by comparing intertidal zone at IT_1 to IT_{10}. The area of the intertidal zones that was in IT_1 but not IT_{10} was calculated. In the Delta, that area was about 3,500 acres. In Suisun Marsh, the area was about 3,000 acres.

Target Methods – Locations Where Ongoing Subsidence Reversal Activities can Reach Intertidal Elevations by 2100

The subsidence reversal zone was calculated using the following formula (see Appendix 2 for an illustration of the methods), assuming a beginning date of 2020 and end date of 2100. The formula produces the band of elevation where ongoing subsidence reversal techniques would accrete land to reach intertidal elevations and prevent the net loss of opportunities to restore tidal wetlands to benefit the ecosystem. This analysis assumes that subsidence reversal activity would be halted once the landscape reaches intertidal elevations.

This was calculated using this given equation:

$$SRT = (MLLW > E) \cup (E - \Delta SLR + \Delta E)$$

SRT is the subsidence reversal target zone. It is areas at intertidal elevation by 2100, given subsidence reversal is used during that period to increase elevations.

Where ***E*** is elevation based on the Delta and Suisun Marsh DEM (Tolentino 2017) which was aggregated to $200m^2$. The DEM was aggregated due to computational limitation. Running the landscape model for multiple scenarios on the aggregated DEM required large live memory resources that dramatically slowed the processing. The aggregation to $200m^2$ improved processing. It was determined that local conditions at a smaller scale likely would better suited for a site-specific analysis conducted by a project proponent rather than a landscape level analysis. The aggregation level of $200m^2$ was chosen because it is discrete enough to be smaller than any reasonable project, but large enough ease any computational bottlenecks.

MLLW is tidal datum for mean lower low water levels.

MHHW is tidal datum for mean higher high water levels.

ΔSLR is expected sea level rise. This analysis assumes a sea level rise of 0.76 meters (2.5 feet) by 2100, with a predicted Golden Gate sea level rise for 50th percentile in RCP 8.5 emission scenario.

ΔE is the change in elevation from subsidence reversal by 2100. The mapped band is based on rates of sediment accretion of 4 cm/yr from Miller et al. 2008.

The target locations identify areas where continued subsidence reversal at 4 cm/yr sediment accretion rate could reach intertidal elevations by 2100. (Figure 2).

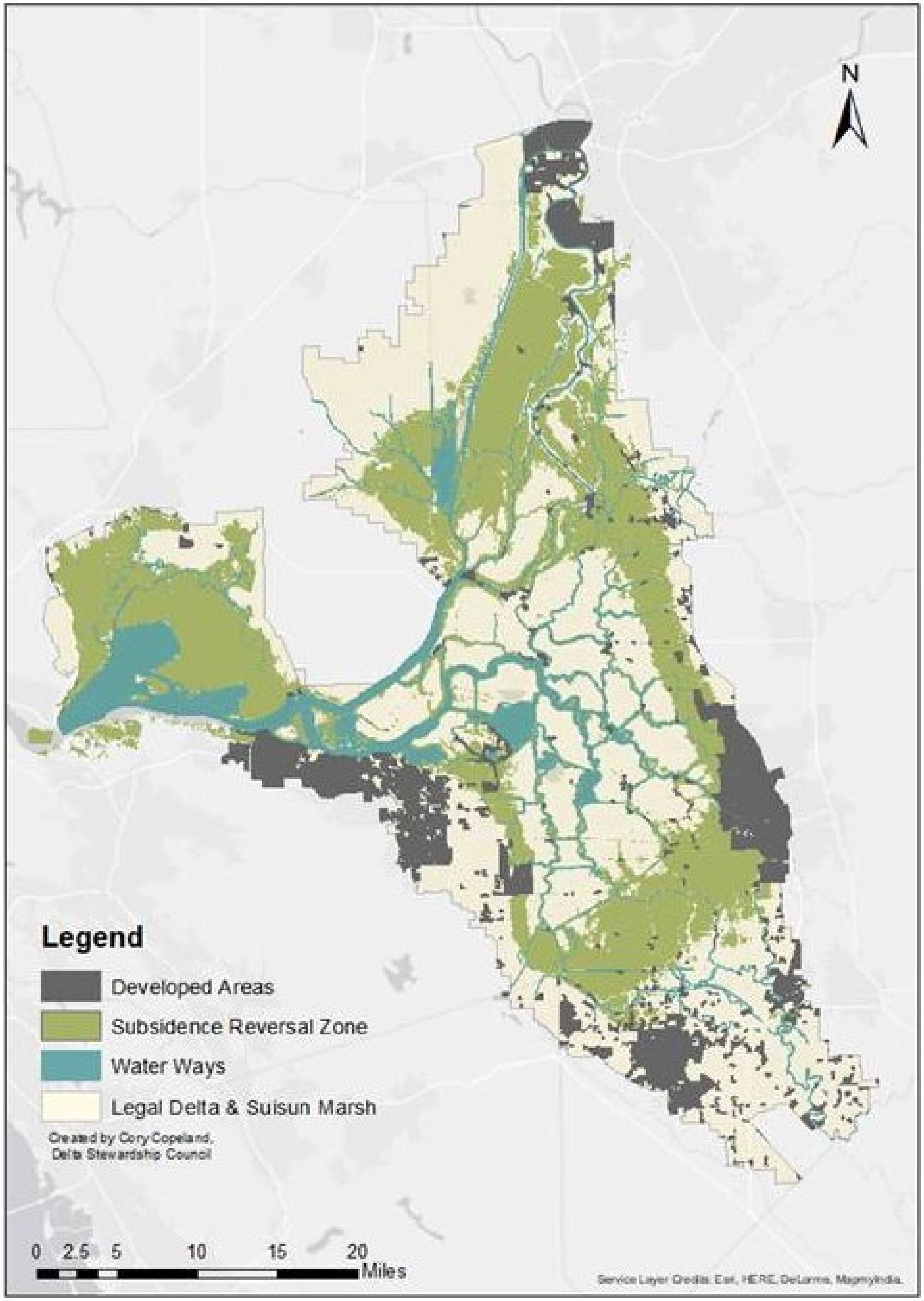

Figure 2. Areas Where Subsidence Reversal Activities, Ongoing from 2030 to 2100, Can Produce Intertidal Elevations by 2100

Figure 2. Areas Where Subsidence Reversal Activities, Ongoing from 2030 to 2100, Can Produce Intertidal Elevations by 2100 (contd.)

Within the boundaries of Suisun Marsh and the Delta, which are drawn as solid gray lines with a solid tan fill, this map illustrates the subsidence reversal zone. The subsidence reversal zone consists of the areas in the Delta and Suisun Marsh (at a 200-meter resolution) that, according to the elevation model used in this performance measure (described in Appendix 1) could reach intertidal elevations through subsidence reversal by 2100.

The subsidence reversal zone covers most of Suisun Marsh and Cache Slough. Concentrated areas in the north Delta, between the Sacramento Deep Water Ship Channel and the Sacramento River, and in the South Delta, north of Tracy and Lathrop, are within the subsidence reversal zone. A band of land surrounding the central Delta is also included in the subsidence reversal zone. Most of the central Delta is not included in the subsidence reversal zone, except for very small and scattered patches of land along the sloughs and rivers. There is minimal land within the subsidence reversal zone at edges of the Suisun Marsh and Delta, where land is above the tidal range.

Alternative formats of this map are available upon request.

This map shows all of the areas in the Delta that are presently at intertidal and shallow subtidal elevations. If subsidence reversal activities are implemented, and these activities continue to accrete land elevation, these areas will reach intertidal elevation by 2100 or sooner. The year 2100 serves as a conservative cutoff. Although there are uncertainties, if the best available science indicates that an area cannot reach intertidal by at least 2100, assuming the conservative assumptions built into the model, then the land is likely too deeply subsided to achieve intertidal elevations through subsidence reversal alone. Developed areas are shown on the map for illustrative purposes.

Appendix 2: Islands at Appropriate Locations

List of islands at appropriate locations to reach elevations that would support potential intertidal restoration by 2100:

DREXLER POCKET
HONKER LAKE TRACT
BRACK TRACT
GRAND ISLAND
TERMINOUS TRACT
MERRITT ISLAND
TYLER ISLAND
PEARSON DISTRICT
SUTTER ISLAND
SHIN KEE TRACT
BISHOP TRACT
LITTLE EGBERT TRACT
EHRHEARDT CLUB
RYER ISLAND
UPPER ANDRUS ISLAND
DEAD HORSE ISLAND
FAY ISLAND
FABIAN TRACT
SHIMA TRACT
SMITH TRACT (LINCOLN VILLAGE)
BYRON TRACT
LISBON DISTRICT
CACHE HAAS AREA
RIO BLANCO TRACT
DREXLER TRACT
WRIGHT-ELMWOOD TRACT
NEW HOPE TRACT
CANAL RANCH TRACT
HOTCHKISS TRACT
WINTER ISLAND
ATLAS TRACT
EGBERT TRACT
NETHERLANDS
PROSPECT ISLAND
GLANVILLE
MCCORMACK-WILLIAMSON TRACT
MAINTENANCE AREA 9
DLIS-11
DLIS-20 (YOLO BYPASS)
CHIPPS ISLAND
MEIN'S LANDING
DLIS-26 (MORROW ISLAND)
DLIS-63 (GRIZZLY ISLAND AREA)
DLIS-48
SUNRISE CLUB
DLIS-52
HONKER BAY
DLIS-62
DLIS-40
DLIS-41 (JOICE ISLAND AREA)
CHIPPS ISLAND SOUTH
DLIS-55
DLIS-47
DLIS-46
DLIS-30
DLIS-36
DLIS-25
DLIS-28
DLIS-29
DLIS-39
DLIS-31 (GARABALDI UNIT)
DLIS-32
DLIS-33
DLIS-44 (HILL SLOUGH UNIT)
DLIS-37 (CHADBOURNE AREA)
DLIS-5
DLIS-49
DLIS-50
UNION ISLAND EAST
UNION ISLAND WEST
MIDDLE ROBERTS ISLAND
LOWER ROBERTS ISLAND
VEALE TRACT
HASTINGS TRACT

Island identifications are those used in the Delta Levee Investment Strategy.

For Assistance

For assistance interpreting the content of this document, please contact Delta Stewardship Council staff.

accessibility@deltacouncil.ca.gov

Phone: 916-445-5511

Performance Measure 4.13: Barriers to Migratory Fish Passage

Performance Measure (PM) Component Attributes

Type: Output Performance Measure

Description

Remediate fish passage at priority barriers and select large rim dams in the Sacramento-San Joaquin River watershed, and screen priority diversions along native, anadromous fish migration corridors within the Delta.[1]

Expectations

Remediating priority fish migration barriers and large rim dams, and screening Delta diversions improves fish migration, reduces fish entrainment, enhances aquatic habitat connectivity, and contributes to anadromous species recovery.

Metric

Priority fish migration barriers and select large rim dams in the Sacramento-San Joaquin River watershed, and unscreened diversions along native, anadromous fish migration corridors in the Delta and Suisun Marsh. This metric will be evaluated annually.

Baseline

Number of fish passage barriers, large rim dams, and unscreened diversions listed in:

1. California Department of Fish and Wildlife (CDFW) 2018 Priority Barriers.

[1] *Remediate* in this context means to provide passage upstream and downstream to migratory fish by constructing, modifying, or removing a barrier.

- For rim dams, remediate means implementing a long-term fish passage program that may include capture, transport, and release of fish at different life stages.
- For unscreened diversions, remediate means to screen the diversion so that juvenile andand adult fish are physically protected from entrainment.

2. Central Valley Flood Protection Program (CVFPP) 2016 Conservation Strategy (Appendix K).
3. Large rim dams in the Sacramento–San Joaquin River watershed identified in the National Marine Fisheries Service's Central Valley Recovery Plan for Central Valley Salmon and Steelhead (2014) with recovery actions.
4. Unscreened diversions along Delta native, anadromous migration corridors listed in the Passage Assessment Database (PAD March 2018 version).

Target

1. By 2030, remediate all (100 percent) priority barriers identified in the 2018 CDFW priority barriers list. For subsequent updates, remediate 100 percent within 10 years of being included in the priority barrier list.
2. By 2030, remediate all (100 percent) of the priority fish migration barriers listed in CVFPP 2016 Conservation Strategy.
3. By 2050, remediate fish passage at all (100 percent) large rim dams in the Sacramento-San Joaquin River watershed.
4. By 2030, prioritize all (100 percent) unscreened diversions along native, anadromous fish migration corridors in the Delta, and by 2050 screen all (100 percent) priority diversions.

Basis for Selection

General Purpose

Several species of native, anadromous fish travel through the Delta and upstream as part of their lifecycle. Instream barriers or unscreened diversions of water from the streams can impede migratory movements. These obstacles can limit or cut off access to spawning and rearing grounds, and to areas that offer refuge from predation, exacerbating stressors that adversely affect overall species survival (CDFW et al. 2014, NMFS 2009 and 2011). Remediating fish passage barriers and screening diversions to prevent fish from being drawn into (entrained) water diversion pipes, is important for the survival of several listed species, including salmonids that migrate through the Delta (CDFW et al. 2014, Merenlender and Matella 2013).

Rim dams are large dams along the rim or edge of the Sacramento and San Joaquin watersheds and Sierra Nevada mountains (Herbold et al. 2018). It is necessary to provide fish passage above rim dams so that fish can access high-elevation, cooler habitat (NMFS 2009).

Remediating all barriers to allow for volitional[2] fish passage will be challenging – especially large rim dams that provide water supply and flood control benefits. However, removing in-stream barriers and implementing fish passage programs at rim dams contributes to native fish population recovery, and increases species resilience and genetic diversity, among other benefits (CDFW et al. 2014, DWR 2014).

This performance measure tracks in-stream fish migration barriers and large rim dams that remediated fish passage to allow for migratory fish to travel upstream and downstream from the barrier. Screening of an unscreened diversion means juvenile or adult fish are physically protected from entrainment.

Barriers, Diversions, and Nonstructural Impediments

The term *barrier* can refer to several different types of impediments including dams, weirs, and low-flow road crossings such as culverts. Barriers can be partial or complete. Some barriers can change with instream flow, and are therefore affected by water year type, weather, sediment loads, and other factors. The term *unscreened diversions* refer to structures that divert water such as water diversion pipes that are not screened and may entrain fish. Water diversion pipes pose a risk to fish, especially salmon and steelhead (Vogel 2011), but also other native species such as Delta smelt, longfin smelt, sturgeon, and Pacific lamprey. Installing fish screens at these diversions is an effective means of preventing fish entrainment (Poletto et al. 2015, Goodman et al. 2017).

Barriers to migration and unscreened diversions are two of many factors affecting fish survival. Other factors include predation, food availability, suitable habitat and refuge, and water temperature (DWR 2014). The size of a fish population and its use of different migration routes are also important (Perry and Skalski 2008). The importance of different migration routes depends on factors such as flow, water operations, and infrastructure. For example, when the Delta Cross Channel is closed, a lower proportion of migrating fish pass through the interior Delta (Perry and Skalski 2008), reducing the negative impact on fish migration of unscreened diversions or barriers in the interior Delta.

In addition to the Delta's importance to fish migration, the Delta provides important nonnatal rearing habitat. In a study of Endangered winter-run Chinook salmon on the Sacramento River by Phillis et al. (2018), early winter-run Chinook appear to exit their

[2] *Volitional* in this context means fish have the opportunity to travel upstream and downstream of the remediated barrier without any human intervention.

natal Sacramento River to rear for extended times at nonnatal habitats (other tributaries) and/or further downstream in the Delta prior to entering the ocean.

Within the Delta, reduced survival during migration may result from a combination of lack of suitable refugia and food sources, challenging environmental conditions (e.g., water temperature), and the cumulative effect of unscreened diversions. There are over 1,458 unscreened diversions on the Delta primary fish migration corridors (SFEI-ASC 2018) with thousands more throughout Delta channels and sloughs (CalFish Passage Assessment Database 2019). While the number of unscreened diversions and the volume of water being diverted can possibly impact fish populations, fish screening can be useful conservation tools to minimize loss of fish (Moyle 2002). Due to limited resources and the large number of these unscreened diversions in the Delta, priority should be given to gathering additional field data about each site (see New ER Recommendation “H”) to allow prioritization and ranking of unscreened diversions for screening.

Rim Dams

Complete barriers are a major obstacle in the Sacramento and San Joaquin River watersheds. Large rim dams in particular have dramatically altered fish passage and access to upstream, cold water spawning habitat (Herbold et al. 2018). Rim dams are estimated to have cut off access for salmonids to approximately 80 percent of their pre-dam accessible habitat (Lindley et al. 2006). This habitat is especially valuable because it is at higher elevation, influenced by snowmelt, and could provide an important climate refuge as water temperatures rise over the remainder of the 21st century. Without access to this habitat, native runs of salmon may become extinct over the coming century. The National Marine Fisheries Service’s (NMFS) Recovery Plan for Central Valley Salmon and Steelhead establishes recovery actions to conduct Central Valley-wide assessment of anadromous salmonid passage opportunities at large rim dams, including assessing quality and quantity of upstream habitat, passage feasibility and logistics, and passage-related costs (NMFS 2014).

The 2009 Biological Opinion on Long-Term Operations of the Central Valley Project and State Water Project (BiOp) notes there are likely to be large impacts on salmonid populations due to inadequate cold water available downstream of large rim dams, especially in dry and critically dry years (NMFS 2009, pp. 659-660). Because of the importance of habitat above large rim dams, it is important to continue to study and find creative solutions to facilitate fish passage past large rim dams.

Climate change introduces new stressors to migratory salmon in the Sacramento and San Joaquin watersheds, including higher water temperatures and more frequent extreme weather events such as droughts. Central Valley rim dams block access to historical, cold-water spawning habitat. A spatially explicit model of salmon population dynamics for Butte Creek indicates that due to flow limits and high temperatures, salmon in the system are vulnerable to extinction without access to upstream areas (Thompson et al. 2012). Historically, the climate has been variable in the Central Valley of California, and salmon have had access to heterogeneous habitats, and genetic and phenotypic diversity among populations was high, resulting in population resilience (Herbold et al. 2018). Current salmon fisheries management seeks to improve salmon adaptive capacity in response to climate change by reconnecting and restoring habitats to facilitate ecosystem processes, providing refuge from temperature stress and predation risk as well as increasing food availability (Crozier et al. 2019).

Prioritization of Barriers

Due to a large number of fish passage barriers located within the Sacramento-San Joaquin watershed, resource agencies prioritize the most important barriers to remediate. CDFW and DWR have different methods of barrier / diversion prioritization but have the same goal of providing fish passage to anadromous fish.

1. CDFW 2018 Priority Barriers, Including Priority Barriers in North Central and Central Regions (Sacramento and San Joaquin River Watersheds)

CDFW Priority Barriers lists prioritize barriers across both coastal and Central Valley watercourses based on these criteria:

1. high likelihood to improve migration for anadromous species
2. availability of recent data of fish and habitat
3. willing partners and land access
4. known political support at a local, state, or national level
5. the site is a barrier to a federal recovery plan "core" population
6. the watercourse is an eco-regional significant watershed
7. CDFW is committed to monitoring before, during and after any barrier improvement project is undertaken
8. the site is considered to be a *keystone barrier*, meaning the barrier was the lower-most in that river or creek

The CDFW priority barrier list is updated on an annual basis with remediated barriers being removed from the list and new barriers being added to the list. Barriers that remain on the annually updated list are not yet remediated (due to factors such as funding, access, or other issues) and continue to be a priority. Remediated barriers are verified by CDFW PAD staff before they are removed from the priority lists (PAD data standards 2014; T. Schroyer, personal communication).

2. Central Valley Flood Protection Plan (CVFPP) Conservation Strategy, Appendix K (DWR 2016), Including the Central Valley Flood System Fish Migration Improvement Opportunities (FMIO) study (DWR 2014)

DWR's CVFPP contains prioritized fish passage barriers in the Central Valley Flood System Fish Migration Improvement Opportunities (FMIO) study and Appendix K of the CVFPP Conservation Strategy. The fish barriers are prioritized using dual metrics in each of the following three categories:

1. Barrier frequency:
   a. Waterway hydrology – frequency of migratory corridor containing water.
   b. Barrier status – total barrier, partial barrier, or temporal barrier.
2. Barrier intensity:
   a. Barrier location in the target area – barriers are given a score to reflect their spatial distribution in the target area. Highest scores for anadromous species are given to barriers farthest downstream.
   b. Species diversity/presence – number of anadromous species that can reach the barrier from upstream or downstream.
3. Upstream habitat:
   a. Upstream miles of waterway – when comparing two or more barriers, the barrier with the most upstream miles of habitat (to the next barrier) gets the highest score.
   b. Type of upstream habitat – spawning, rearing, and holding habitats.

DWR's priority barriers list does not consider diversions, and there are no plans to regularly update DWR prioritization lists. The lists from these studies are included because they represent the most in-depth analysis of barriers, and opportunities for improvements, currently available.

Large Rim Dams in the National Marine Fisheries Service's Recovery Plan

The National Marine Fisheries Service's (NFMS) Recovery Plan for Central Valley Salmon and Steelhead establishes a strategic approach to recovery which identifies critical recovery actions for the Central Valley as well as watershed and site-specific recovery actions (NOAA 2014, p 102). Each major tributary to the Central Valley watershed contains specific recommended recovery actions including evaluating fish passage at large rim dams.

Unscreened Water Diversions

CDFW has prioritization criteria specific to unscreened diversions and develops a priority list of regional annual water diversions for screening based on the following ranking criteria: presence of listed and at-risk species, number of other diversions in the watershed, location of the diversion, intake orientation, duration of pumping, and ongoing efforts in cooperation with the diverter to screen the facility.

However due to limited surveys and access within the Delta, water diversions within the Delta lack sufficient details to be able to apply the ranking criteria to them (T. Schroyer, personal communication). Therefore, a first step in prioritizing unscreened diversions within Delta is to gather the additional field data (see New ER Recommendation “H”).

Linkages to Delta Reform Act and the Coequal Goals

Delta Reform Act

Habitat fragmentation and limited access to spawning and rearing grounds are major stressors to conservation and recovery of salmon species. Entrainment of fish into unscreened water diversions increases mortality of native resident and migratory fish species. Achieving the target in this performance measure would support the following characteristics of a healthy Delta, as identified in the Delta Reform Act:

- **“Viable populations of native resident and migratory species.” (Water Code section 85302(c)(1)).** Remediating instream barriers and screening Delta diversions is important for the survival of several listed species by improving fish migration, reducing fish entrainment, enhancing aquatic habitat connectivity, and contributing to anadromous species recovery.

- **“Functional corridors for migratory species.” (Water Code section 85302(c)(2)).** Instream barriers and unscreened water diversions impede migratory movements, and they limit or cut off access to spawning and rearing grounds and areas that offer refuge from predation (CDFW et al. 2014, NMFS 2009 and 2011). Remediating instream barriers and screening Delta diversions restores corridors for migratory species, enhances aquatic habitat connectivity, and opens access to salmon spawning and rearing grounds.

- **“Reduced threats and stresses on the Delta ecosystem.” (Water Code section 85302(c)(4)).** Instream barriers and unscreened water diversions exacerbate stressors that adversely affect migratory fish species (CDFW et al. 2014, NMFS 2009 and 2011). Allowing migratory salmon to access historical, cold-water spawning habitat blocked by rim dams will improve salmon adaptive capacity by providing refuge from temperature stress and predation risk (Crozier et al. 2019).

- **"Conditions conducive to meeting or exceeding the goals in existing species recovery plans, and state and federal goals with respect to doubling salmon populations."** (Water Code section 85302(c)(5)). Meeting the target of this measure will contribute to the recovery of salmon populations by improving fish migration and opening access to additional spawning and rearing grounds.

Achieving the target in this performance measure supports the following subgoal and strategy for restoring a healthy ecosystem: **"Establish migratory corridors for fish, birds, and other animals along selected Delta river channels." (Water Code section 85302(e)(2)).**

This performance measure tracks priority fish migration barriers. Remediating fish passage at priority barriers restores corridors for migratory species, enhances aquatic habitat connectivity, and opens access to salmon spawning and rearing grounds, contributing to the Doubling Goal for Central Valley Chinook Salmon Natural Production (PM 4.6).

Delta Plan Core Strategy

4.4 Protect Native Species and Reduce the Impact of Nonnative Invasive Species.

Methods

Baseline Methods

The baseline is all of the priority barriers identified by CDFW and DWR—99 Large rim dams in the Sacramento-San Joaquin Delta watershed, and 1,458 unscreened diversions along migratory routes in the Sacramento-San Joaquin Delta and Suisun Marsh.

The **priority barriers** listed in Tables 1 and 2 below are based on the CDFW 2018 Regional Fish Passage Priority List and DWR's CVFPP Conservation Strategy (Appendix K, 2016). The methods used by CDFW and DWR to select these barriers are described in the "Basis for Selection" section (p. 6-7) of this document. DWR stated that there will be no regular updates to their list, thus the list will remain as a static baseline (consisting of the current barriers in Tables 1 and 2 under column two). While CDFW updates their priority barrier lists annually, the performance measure target is based on the CDFW 2018 Regional Fish Passage Priority List.

The **large rim dams** identified (Table 3 in Methods) were selected because of their targeted recovery actions specified in the National Marine Fisheries Service's (NMFS) 2014 Recovery Plan. Each river identified contains several listed recovery actions. The Recovery Plan identifies an action for most rivers in the Central Valley involving large rim dams and smaller downstream dams, which calls for planning for development and/or implementation of a program to reintroduce salmon species and steelhead to historic upstream habitats. NMFS recommends that programs should include feasibility studies, habitat evaluations, fish passage design studies, and a pilot project. Each recovery action also identifies potential collaborators, duration, and estimated costs (NMFS 2014). Current examples of fish passage programs are shown in the "Interim Performance Assessment" section of this document.

The **Delta unscreened diversions** baseline was identified by using the PAD March 2018 GIS layer. The data was filtered for "SITETYPE" = "diversions" and "BarStatus" = "unscreened" and clipped to only count diversions within the Delta. Next, it was further clipped to only count unscreened diversions that are on anadromous fish migration corridors. The total count of unscreened diversions is 1,458.

Table 1. Comparative List of Priority Fish Migration Barriers Identified in the Sacramento River Watershed

Sacramento River Fish Migration Barriers	Priority Barrier in CVFPP 2016 Conservation Strategy	Priority Barrier in CDFW 2018
Lisbon Weir	Yes	No
Yolo Bypass Road Crossings	Yes	No
Cache Creek Settling Basin	Yes	No
Fremont Weir[1]	Yes	Yes
Oroville-Thermalito Complex	Yes	No
Knights Landing Outfall Gates (KLOG)[2]	Yes	No
Tule Canal Crossings	Yes	No
Sacramento Weir	Yes	No
Sunset Pumps Diversion Dam	Yes	Yes
Sutter Bypass Weir No. 1	Yes	Yes
Sutter Bypass (multiple structures)	Yes	No
Tisdale Weir	Yes	Yes
Moulton Weir	Yes	No
One-Mile Dam	Yes	Yes
Big Chico Creek Gates (Five-Mile Dam)	Yes	Yes
Lindo Channel Gates	Yes	No
Sewer Pipe Crossing, Dry Creek	No	Yes
Battle Creek Restoration Project Dams (8 total barriers)	No	Yes
Antelope Creek Edwards Diversion	No	Yes
Deer Creek Stanford Vina Dam Fish Ladders		Yes
Mill Creek Fish Passage Project - Upper Dam		Yes

Sources: DWR 2016 and CDFW 2018

Key:
CDFW = California Department of Fish and Wildlife
CVFPP = Central Valley Flood Protection Plan

Notes:
[1] Upstream migration over the Fremont Weir was partially addressed in 2018. However, it remains a barrier to downstream migration until overtopping under high flow conditions.
[2] The KLOG had operational gates added in 2015 as part of the EcoRestore project. It is operated as an intentional barrier to keep migrating salmonids in the mainstem of the Sacramento River, under certain conditions.

Table 2. Comparative List of Priority Fish Migration Barriers Identified in the San Joaquin River Watershed

San Joaquin River Fish Migration Barriers	Priority Barrier in CVFPP 2016 Conservation Strategy	Priority Barrier in CDFW 2018
San Joaquin River Headgates	Yes	No
Sack Dam	Yes	Yes
Mendota Dam	Yes	Yes
San Joaquin River Control Structure	Yes	No
Donny Bridge	Yes	No
Lost Lake Rock Weir #1 (Lower)	Yes	No
Mariposa Bypass Control Structure	Yes	No
Mariposa Bypass Drop Structure	Yes	No
Eastside Bypass Rock Weir	Yes	No
Eastside Bypass Control Structure	Yes	No
Dan McNamara Road Crossing	Yes	No
Merced Refuge Weir #1 (Lower)	Yes	No
Merced Refuge Weir #2 (Upper)	Yes	No
Avenue 21 County Bridge	Yes	No
Ave 18½ County Bridge	Yes	No
Pipeline Crossing	Yes	No
Eastside Bypass Drop 2 (Upper)	Yes	No
Bellota Weir	No	Yes
Merced River Cowell Agreement Diverters (CAD) Wingdams (7 total barriers)	No	Yes
Eastside Bypass Drop 1 (Lower)	Yes	No
Chowchilla Bypass Control Structure	Yes	No
Hosie Low Flow Road Crossing	No	Yes
Central California Traction Railroad Bridge	No	Yes

Sources: DWR 2016 and CDFW 2018

Key:
CDFW = California Department of Fish and Wildlife
CVFPP = Central Valley Flood Protection Plan

Table 3. Large Rim Dams Identified in Recent Recovery Plan Biological Opinion for Central Valley Chinook Salmon and Steelhead Passage

Rim Dam Name	Associated Downstream Dams	Tributary Name	Watershed
Shasta Dam	Keswick Dam	Sacramento River	Sacramento River
Folsom Dam	Nimbus Dam	American River	Sacramento River
Oroville Dam	Thermalito Diversion Dam	Feather River	Sacramento River
New Bullards Bar Dam	Englebright Dam and Daguerre Point Dam	Yuba River	Sacramento River
Friant Dam	N/A	San Joaquin River	San Joaquin River
New Melones	Goodwin and Tulloch Dam	Stanislaus River	San Joaquin River
New Don Pedro	La Grange Dam	Tuolumne River	San Joaquin River
New Exchequer Dam	Crocker-Huffman Dam Merced Falls Dam McSwain Dam	Merced River	San Joaquin River
Pardee Dam	Camanche Dam	Mokelumne River	San Joaquin River

Source: NMFS 2014 and 2009

Target Methods

The **DWR's CVFPP priority barriers** will have a target of 100% remediation of the listed barriers by 2030. A 100% remediation target by 2030 was selected due to several current timelines and estimates of fish passage barrier remediation projects. Some fish passage barrier projects are already being implemented such as the Fremont Weir in the Yolo Bypass and Mendota Dam on the San Joaquin River. Other barriers such as Lisbon Weir, Yolo Bypass Agricultural Crossings, and East Side Bypass on the San Joaquin River will begin project implementation in 2020 or planned for in the following years. Additional assessment needs for barriers are identified in Appendix K of the CVFPP.

CDFW's priority barrier list is updated annually and has a target of 100% remediation of the listed barriers within 10 years of the barrier being listed in the priority list. Each new barrier listed in subsequent lists will be tagged with the year it was added to the priority list. A 100% remediation target within 10 years was selected because it provides enough time for the responsible agencies to carry out the remediation. In addition, a 10-year time frame is considered to be a realistic goal (T. Schroyer, personal communication).

- E.g. 2018 Priority Barriers (last updated October 2019) will have a target of 100% remediation by 2030. Barriers added in 2022, will have a 100% remediation target by 2032 and so on.

Large rim dams are to be 100% remediated by 2050. This metric will depend on future or current feasibility studies being completed and fish passage programs being implemented. Further discussion about feasibility studies are located in the "interim performance assessment" section.

Unscreened diversions will have a target of 100% remediation by 2050. This metric will depend on future prioritization schemes because it is currently limited within the Delta compared to other regions. Identifying priority water diversions for screening using ranking criteria specific to unscreened diversion is set as a near-term target (100% prioritized by 2030). Screening of all priority diversions is expected by 2050.

Data Sources

Primary Data Sources

This primary data source will be used for tracking this performance measure annually:

1. California Fish Passage Assessment Database (PAD). The PAD is an "inventory of known and potential barriers to anadromous fish in California," and includes all instream dams, including the rim dams, in the Sacramento-San Joaquin River watershed. The PAD database reports the fish passage status of the barriers, dams, and unscreened diversions.
    a. Content: Updated fish passage status of remediated barriers.
    b. Update frequency: Three times per year.

Alternative Data Sources

Alternative data sources will be used if the primary data sources become unavailable or insufficient. These data sources were used in compiling the passage priorities, and updates to fish passage barrier priorities can be used concurrently with the primary data sources as a reference, or as supplemental information.

1. CDFW Watershed Restoration Grants Branch. CDFW provides a list of fish passage priorities in grant proposal solicitation notices. Proposition 68 awards grants to projects that improve a community's ability to adapt to the unavoidable impacts of climate change; or ones that improve and protect coastal and rural economies, agricultural viability, wildlife corridors, or habitat. Proposition 1 awards grants to projects that meet objectives of reliable water supplies, restoration of important species and habitat, and more resilient, sustainably managed water resources system.
    a. Content: Updated prioritization of fish passage barriers to be available for Prop 1 and Prop 68 proponents.

    b. Update frequency: Annually.

2. Updates to Central Valley Flood Protection Plan (CVFPP) Conservation Strategy. DWR updates the Conservation Strategy as a system-wide conservation plan to support integrated flood system planning and integration of environmental stewardship into the CVFPP.
    a. Content: Updated prioritization of fish passage barriers within the Central Valley Flood Protection Plan.
    b. Update frequency: Every five years.

Process

Data Collection and Analysis

Every year, Council staff will update the status of this performance measure by:

1. For all of the identified priority barriers in the PAD priority list (Table 1 and 2), identify those that were remediated each year by downloading their new priority lists at calfish.org.
    a. Add additional barriers to the overall measure list (tagged with the year of their addition) that were added to the PAD priority list.
        i. Count the total number of barriers that were remediated with verification from CDFW staff.
        ii. Update the number of total remediated barriers for CDFW, with context for each barrier if possible.
2. For the identified barriers in DWR's CVFPP priority barriers (Tables 1 and 2), contact DWR staff to receive information about priority barrier status.
    a. If any of the listed barriers are remediated, update the number of total remediated barriers for the CVFPP list with context for each barrier if possible.
3. For large rim dams, contact the responsible agencies (U.S. Department of the Interior, Bureau of Reclamation (Reclamation); U.S. Army Corps of Engineers; etc.) regarding the statuses of feasibility studies, pilot programs, and other fish passage related efforts. Any relevant efforts at these dams will be actively tracked and noted.
4. For unscreened diversions:

a. Review results of CDFW water diversions screening prioritization and inquire about the status of the prioritization scheme for unscreened diversion within the Delta.

b. To view status of unscreened diversions remediation, download the most recent PAD GIS dataset (annually updated) and check the total number of unscreened diversions. Verify with CalFish staff if the number if accurate and for context.

Interim Performance Assessment

Along with the annual evaluation and tracking of this performance measure, performance assessment in relation to interim milestones will be conducted every five years, coinciding with the Delta Plan five-year review process. The interim milestones are set to allow for assessment of short-term progress toward the performance targets.

Interim Milestones – Priority Barriers

1. Interim progress will be tracked against the baseline 2018 priority list with a milestone of 50% remediated barriers by 2025.
2. CDFW conducts a statewide fish passage barrier prioritization process annually. Annual changes to prioritized barriers (additional barriers) will be tracked and compared to the 2018 baseline barriers.
    a. Council staff will coordinate with CDFW fish passage coordinator to obtain contextual information for newly added and removed priority barriers, and inquire about priorities, timelines, and feasibility.
3. Updates or changes to the CVFPP priority barrier list are not expected. Interim milestone is remediation of 50% of priority barriers by 2025.

Interim Milestones - Rim Dams

4. Fish passage feasibility studies initiated, ongoing, or completed for the listed large rim dams.
    a. If fish passage is found feasible at the dam site, this PM will track and report the progress of the study and recovery plan.
    b. If fish passage is found infeasible at the dam site, what additional efforts are being conducted to remediate Rim Dams?
    c. Are there current feasibility studies being conducted? Progress on existing efforts will be tracked including:
        i. Reclamation’s Shasta Dam Fish Passage Evaluation, https://www.usbr.gov/mp/bdo/shasta-dam-fish-pass.html. This is part of

Reclamation's Fish Passage program that involves evaluation of the reintroduction of winter-run and spring-run Chinook salmon and steelhead above Shasta Dam. The goal is to increase the geographic distribution, abundance, productivity, and spatial distribution, and to improve the life history, health, and genetic diversity of the target species. Folsom and New Melones Dams are also included in Reclamation's Fish passage program and will be addressed in independent planning studies (Reclamation 2015).

ii. Yuba Salmon Partnership Initiative. (YSPI) http://www.dfg.ca.gov/fish/Resources/Chinook/YSPI/. The YSPI is a collaboration between CDFW, NOAA, Yuba County Water Agency, and several other entities to return spring-run Chinook salmon and possibly steelhead to more than 30 miles of the north Yuba River (New Bullards Bar dam). The program would truck juvenile salmon in the winter downstream and recover them in spring to be trucked up New Bullards Bar dam (YSPI 2015).

iii. The Turlock Irrigation District and Modesto Irrigation District included a fish passage assessment for reintroduction of anadromous fish above Don Pedro Dam in their Environmental Impact Statement for Hydropower Licenses, https://www.ferc.gov/industries/hydropower/enviro/eis/2019/02-11-19-DEIS/P-2299-082-DEIS.pdf. Additional information of their efforts regarding fish passage can be found in the document at pages 3-162 to 3-170.

iv. The Upper Mokelumne Salmonid Restoration Team (SRT) is a collaboration of state, federal, local, and NGO agencies that aims to reestablish a successfully reproducing population of fall-run Chinook salmon and/or Central Valley steelhead in the upper Mokelumne River (Cramer Fish Sciences 2018). In 2018, they completed an assessment of the potential for Chinook salmon reintroduction above Pardee Dam, http://www.foothillconservancy.org/dl.cgi/1552580969_22399.f_doc_pdf.pdf/UM_2018_final.pdf.

5. Progress and findings from the Central Valley-wide assessment of anadromous salmonid passage opportunities at large rim dams including the quality and quantity of upstream habitat, passage feasibility and logistics, and passage-related costs (NOAA 2014).

Interim Milestones - Unscreened Diversions

6. Field data is collected at unscreened diversions, in addition to diversion size and site location, to provide additional information allowing prioritization of

unscreened diversions. The large majority of Delta agricultural diversions is below 100 cfs, but large unscreened diversions located on important migratory routes may remain.

7. Conduct prioritization of unscreened diversions for screening priorities following CDFW statewide prioritization protocol. The prioritization process includes contribution of the diversion to the cumulative loss of fishes to the system and the impact of this contribution on fish populations, especially those of declining species. Such an evaluation could help determine priorities for spending limited funds available for fish conservation (Moyle 2002 Memo).
8. Based on prioritization results, screen high priority barriers.

Process Risks and Uncertainties

As previously discussed in the basis for selection, it is unlikely that all in-stream barriers will be remediated but remediating the prioritized barriers will benefit native fish survival and resilience.

Large rim dams provide water supply and flood control benefits, and the technological solutions to upstream and downstream fish passage are complex. Interim steps include conducting Central Valley-wide assessment of anadromous salmonid passage opportunities. This also includes preparing site-specific feasibility studies to evaluate upstream habitat quality and quantity, passage feasibility and logistics, passage-related costs, and reintroduction of the species.

Similarly, to screen over 1,400 unscreened diversions within the Delta priority migration corridor is unlikely. Ranking the diversions for screening priorities is an important initial step to focus limited funds available for fish conservation for screening projects with highest impact of populations.

Process risks and uncertainties related to this measure are:

1. Environmental variability such climate, ocean, hydrology, freshwater flow, and native fish populations
2. Gaining land access and willing partners from landowners
3. Support from local, state, or federal agencies due to differing agency priorities and funding
4. Acquiring and implementing suitable fish passage technologies

Reporting

Every year, Council staff will report the status of this performance measure by:

1. Posting updates on the Performance Measures Dashboard.
2. Providing results in the Council's annual report (published in January).
3. Communicating management-relevant results at Council and Delta Plan Interagency Implementation Committee (DPIIC) public meetings.

Every five years, Council staff will assess and report the status of this performance measure by:

1. Communicating findings in the five-year review of the Delta Plan.
2. Informing the Council's adaptive management process and other decision-making.

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Performance Measure 4.14: Increased Funding for Restoring Ecosystem Function

Performance Measure (PM) Component Attributes

Type: Output Performance Measure

Description

Increased funding for projects that possess attributes to restore ecosystem functions and support a resilient, functioning Delta ecosystem.

Expectations

Increased funding for projects that restore hydrological and geomorphic processes, are large-scale, improve connectivity, support native vegetation communities, and contribute to recovery of special-status species contributes to restoring ecosystem functions and supports a resilient, functioning Delta ecosystem (Ecosystem Restoration Tier 1 or 2 attributes).

Metric

Project funding of covered actions that file a certification of consistency under New ER Policy “A” (Disclose Contributions to Restoring Ecosystem Function). This metric excludes funding for projects that do not include protection, enhancement, or restoration of the Delta ecosystem. This metric will be reported annually.

Baseline

Set at zero as of the effective date of New ER Policy “A.”

Target

By 2030, 80 percent of total funding for covered action projects that file certifications of consistency with New ER Policy “A” is for projects with Ecosystem Restoration Tier 1 or 2 attributes.

Basis for Selection

To achieve the subgoals (Water Code section 85302(e)) for restoring the Delta ecosystem set forth in the Delta Reform Act, the Delta Plan recommends implementation of projects with specific priority attributes that restore ecosystem functions and support a resilient, functioning Delta ecosystem, and an increase in funding for those high priority projects. High priority projects restore hydrological and geomorphic processes, are large-scale, improve connectivity, support native vegetation communities, and contribute to recovery of special-status species. This measure tracks the total funding of high-quality conservation projects proceeding through the covered action process. A covered action, per Water Code section 85057.5, is a plan, program, or project as defined pursuant to Section 21065 of the Public Resources Code. This measure evaluates the percentage of funding for high-tier projects according to the definition in New ER Policy “A” (Chapter 4, Appendix 3A).

A project’s tier is determined by project proponents, based on the expected ecosystem benefits for conservation projects in the Delta (Appendix 3A of the Delta Plan). New ER Policy “A” requires proponents to disclose which priority attributes their project supports. The priority attributes are characteristics of the protection, restoration, and enhancement projects which best available science indicates are critical to achieving the characteristics of a healthy Delta ecosystem. This is further described in Appendix 3A of the Delta Plan. Below is a summary of priority attributes for ecosystem restoration actions in the Delta:

1. **Restoring Hydrological, Geomorphic, and Biological Processes** – Targeting the reestablishment of hydrological, geomorphic, chemical, and biological processes in conservation projects, also termed *process-based restoration*, is key to improving habitat characteristics related to the spatial arrangement of habitat patches, vegetation community composition and structure, and habitat requirements of sensitive specialist species.
2. **Being Large-Scale** – Conservation projects that incorporate large spatial scales and long time frames will increase the likelihood of creating natural systems capable of sustaining desired functions in uncertain future environmental condition (Peterson et al. 1998, SFEI-ASC 2016). Critical biotic interactions and physical processes depend on appropriate levels of heterogeneity (Larkin et al. 2017) made possible by large-scale projects. Large intact core areas with minimal human intervention are important for facilitating the ecological interactions that are important to species persistence (Soule and Terborgh 1999).
3. **Improving Connectivity** – Connectivity is essential for the long-term persistence of native species. In the Delta, unobstructed flow through the channel system,

lateral connections between channels and floodplains, and horizontal connections between surface and groundwater are different facets of connectivity. Nutrient and carbon cycling, vegetation community patch dynamics, and species-habitat interactions improve with increased connectivity (Vannote et al. 1980, Naiman et al. 1988, Ward 1989, Junk et al. 1989, Poff et al. 1997, Naiman and Decamps 1997). The various aspects of connectivity are crucial to the ability of riparian and wetland systems to support biodiversity. Improving connectivity will increase ecosystem resilience and adaptive potential in the face of a rapidly changing climate (Naiman et al. 1993, Seavy et al. 2009).

4. **Increasing Native Vegetation Cover** – The loss of native vegetation cover has greatly reduced habitat complexity in the Delta over the last 160 years, completely altering aquatic and intertidal food-web dynamics (Moyle et al. 2010, Whipple et al. 2012). This loss of ecosystem complexity has been coupled with and exacerbated by substantial reduction in land-water connections (SFEI-ASC 2014 and 2016). Restoration of complex ecosystems will require reestablishment of native vegetation communities and the underlying processes that support their recruitment, disturbance regimes, and community succession. Restoring a variety of native vegetation cover types can promote ecological resilience and enhance native biodiversity by providing a range of habitat options for species, thus expanding the types and numbers of species that a landscape can support.
5. **Contributing to the Recovery of Special-Status Species** – At least 35 native plant species and 86 fish and wildlife species in the Delta are imperiled by human activities, and they are at varying risks of either local extirpation or outright extinction. Habitat loss and degradation, and the resulting impacts on food-web dynamics, have been a major cause of the at-risk status of these species. Supporting ecosystem function such as nutrient transfer and primary production is an important requirement for the recovery of these species.

Tier 1 projects have all five priority attributes. Tier 2 projects have priority attribute 5 (contributing to the recovery of special-status species) and three of the remaining four priority attributes. New ER Policy “A” (Disclose Contributions to Restoring Ecosystem Function) requires project proponents to disclose whether individual covered actions possess the listed priority attributes needed to certify consistency with the Delta Plan.

Linkages to Delta Reform Act and the Coequal Goals

Delta Reform Act

Achieving the Delta Reform Act vision for the Delta ecosystem, requires the reestablishment of tens of thousands of acres of functional, diverse, and interconnected habitat. Funding is needed to implement large-scale restoration projects and to support multi-benefit projects that go beyond impact mitigation. State and local land use actions, identified as *covered actions* pursuant to 85057.5, must be consistent with the Delta Plan (Water Code section 85022(a)). Per 85057.5, a covered action is a plan, program, or project as defined pursuant to section 21065 of the Public Resources Code that meets all of the following conditions:

1. Will occur, in whole or in part, within the boundaries of the Delta or Suisun Marsh
2. Will be carried out, approved, or funded by the state or a local public agency
3. Is covered by one or more provisions of the Delta Plan
4. Will have a significant impact on achievement of one or both of the coequal goals or the implementation of government-sponsored flood control programs to reduce risks to people, property, and state interests in the Delta

Projects with high-priority attributes that restore ecosystem functions and support a resilient, functioning Delta are critical to achieving the following characteristics of a healthy Delta ecosystem described in Water Code section 85302(c):

- "Viable populations of native resident and migratory species" (Water Code 85302(c)(1)).
- "Functional corridors for migratory species" (Water Code 85302(c)(2)).
- "Diverse and biologically appropriate habitats and ecosystem processes" (Water Code 85302(c)(3)).
- "Reduced threats and stresses on the Delta Ecosystem" (Water Code 85302(c)(4)).
- "Conditions conducive to meeting or exceeding the goals in existing species recovery plans and state and federal goals with respect to doubling salmon populations" (Water Code 85302(c)(5)).

Increased funding and consequently implementing projects with high-priority attributes contributes to improved "health of the Delta's estuary and wetland ecosystem for supporting viable populations of aquatic and terrestrial species, habitats, and processes, including viable populations of Delta fisheries and other aquatic organisms" (Water Code 85211(a)).

Delta Plan Core Strategy

4.2 Restore Ecosystem Function.

Methods

Baseline Methods

Set at zero as of the effective date of New ER Policy "A"

Target Methods

The Delta Reform Act established a process for qualifying projects to establish consistency with the Delta Plan (Water Code section 85022). This means that a state or local agency proposing to undertake a qualifying action (covered action) must submit to the Council a written certification of consistency with detailed findings as to whether the covered action is consistent with Delta Plan regulations. Any person may appeal a certification of consistency to the Council.

The Council's covered action website and the associated database (2020) provide access to the certified covered actions and related details, including the estimated project cost. Under New ER Policy "A," certified projects include, when applicable, a disclosure of project tiers, priority attributes supported by the project, and information on the project cost.

Each certification of consistency has three sections. Section 1 is the agency profile where project proponents provide details about the agency filing to certify consistency with the Delta Plan. Section 2 is a covered action profile where the project proponent provides information about the covered action. The proponent discloses an estimated project cost along with a description of the project, a timeline, and other materials describing the project. The estimated project funding from this section of the consistency filing will be used as the primary data source. Section 3 is a policy-by-policy description of the project proponent's findings regarding consistency with the Delta Plan. With regard to each policy, the proponent may find that the covered action is consistent, inconsistent, or that the policy is not applicable to the covered action. Any certification of consistency to which New ER Policy "A" applies will be tracked for this performance measure. A covered action will only be counted under this performance measure after a consistency certification has been filed.

Data Sources

Primary Data Sources

This is the primary data source to be used to track this performance measure:

1. Delta Plan Covered Actions Website. A state or local agency proposing to undertake a qualifying action (covered action) must submit a certification of consistency with detailed findings as to whether the covered action is consistent with the Delta Plan. Covered actions certifications are available on the Council's website.
    a. Content: Covered action certification of consistency document including disclosed amount of funding for the whole project (project cost).
    b. Update Frequency: As certifications are submitted.

Alternative Data Sources

Alternative data sources will be used if project funding is not disclosed on the Council's covered actions website. Alternative data sources can be used concurrently with the primary data source, depending on best available science and the availability of the primary source.

1. California Environmental Quality Act (CEQA) Clearinghouse
    a. Data Source: Project CEQA environmental impact report (EIR) includes cost of project alternatives considered. Covered actions have an associated EIR, as Delta Plan consistency certification is triggered by the CEQA process.
    b. Update Frequency: As EIR project files are submitted.

Process

Data Collection and Analysis

Every year, Council staff will update the status of this performance measure by:

1. Downloading covered actions project documents from the covered actions website that certify under New ER Policy “A.” Funding only for projects that file a certification of consistency under New ER Policy “A” will be included. The calculation will exclude funding for projects that do not include protection, enhancement, or restoration of the Delta ecosystem (and will not need to certify under New ER Policy “A”).
2. Summing the total cost of all projects under New ER Policy “A.”
3. Filtering project documents by ecosystem restoration tier.
4. Summing the total cost of projects in ecosystem restoration Tier 1 and Tier 2.
5. Calculating the percentage of cost of projects in Tier 1 and Tier 2 with the total cost of all projects under New ER Policy “A.”
6. Displaying results on the Performance Measures Dashboard.

Interim Performance Assessment

To evaluate short-term progress before the target date, an interim milestone is set as follows:

By 2025, 40 percent of the total funding for covered action projects that file certification of consistency with policy ER ‘A’ is for projects with Ecosystem Restoration Tier 1 or 2 attributes.

Process Risks and Uncertainties

A linear increase in percent of funding for projects with Ecosystem Restoration Tier 1 or Tier 2 attributes may not be a reasonable expectation due to long lead times in restoration projects’ development and implementation. Uncertainty exists in time lags between a covered action filing of certification of consistency and on-the-ground implementation, and in the trajectory of restoring ecosystem functions.

Reporting

Every year, Council staff will report the status of this performance measure by:

1. Posting updates on the Performance Measures Dashboard
2. Providing results in the Council's annual report (published in January)
3. Communicating management-relevant results at Council and Delta Plan Interagency Implementation Committee (DPIIC) public meetings
4. Presenting findings at technical interagency groups, professional gatherings, and conferences

Every five years, Council staff will assess and report the status of this performance measure by:

1. Communicating findings in the five-year review of the Delta Plan.
2. Informing the Council's adaptive management process and other decision-making.

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Performance Measure 4.15: Seasonal Inundation

Performance Measure (PM) Component Attributes

Type: Outcome Performance Measure

Description

Restoring land-water connections to increase hydrologic connectivity and seasonal floodplain inundation.

Expectations

Increased hydrologic surface water connectivity and increased frequency of seasonal inundation contributes to achieving a healthy Delta ecosystem and viable populations of native species.

Metric

Acres within the Sacramento-San Joaquin Delta and Suisun Marsh that are:

1. Hydrologically connected to fluvial and tidally influenced waterways.
2. A nontidal floodplain[1] area that inundates[2] at least once every two years.

Metric will be evaluated annually.

Baseline

As of the year 2018:

1. An estimated 75,000 acres of land physically connected to the fluvial river and tidal system.

[1] Area that is inundated on a two-year recurrence frequency and is connected via surface water to the fluvial river or tidal system.

[2] There is no depth threshold for the inundation analysis, as inundation occurs at any depth. While depth of inundation is important for ecological processes, the available data do not include depth measurements.

2. Approximately 15,000 acres of the connected land inundated at a two-year interval, calculated as a long-term average for 1985-2018.

Target

By 2050:

1. Additional 51,000 acres added to the 75,000-acre baseline that are physically connected to the fluvial river and tidal system, for a total of 126,000 acres.
2. At least an additional 19,000 acres of nontidal floodplain area is inundated on a two-year recurrence interval, for a total of 34,000 acres.

Basis for Selection

Since the 1800s, 91 percent of historical wetland habitat in California has been lost (Dahl 1990), including 95 percent of Central Valley floodplain habitat (Opperman et al. 2010, Whipple et al. 2012). In the Delta, most of these wetlands and floodplains have been drained and converted to agricultural land use (SFEI-ASC 2014). Although most of the natural wetlands no longer remain, some agricultural land, floodways, and floodplains can provide similar functions, including greatly increased aquatic food production and transfer of nutrients to the fluvial system compared to other converted land uses (Moyle and Mount 2007, Corline et al. 2017, Katz et al. 2017). However, in order for these functions to be maintained or restored, areas must be hydrologically connected via surface water, and inundated for at least part of the year (Sommer et al. 2001a, Jeffres et al. 2008, Opperman et al. 2010, Katz et al. 2017).

The ecological health of the Delta is fundamentally dependent on the reestablishment of more natural inundation patterns and land-water connections. It is expected that increased area and frequency of floodplain inundation will result in enhanced primary productivity, an improved food web and flow of nutrients that better support a healthy and functioning ecosystem (Ahearn et al. 2006, Cloern et al. 2016). Floodplain inundation occurs when rivers or waterways exceed their channel capacity and flow onto adjacent lands. In the Delta, this most often occurs during winter and spring months.

Restoration of land-water connections to provide the biological benefits of floodplain inundation requires two components: 1) physical or hydraulic surface water connectivity for water to flow onto land; and 2) sufficient flow of water to inundate these connected areas (Merenlender and Matella 2013).

Connectivity

Surface water connectivity between areas of fresh and saline water, riverine, riparian, floodplain, and other aquatic and terrestrial transitions is critical for the health and productivity of aquatic ecosystems (Opperman 2012, SFEI-ASC 2014, Cloern et al. 2016, SFEI-ASC 2016). The aquatic food web benefits from an exchange between land and water habitats (Polis et al. 1997, Ahearn et al. 2006, Opperman et al. 2010). However, transformation of the Delta from its mid-1800s condition has also increased connectivity of some waterways in manners that may negatively affect ecosystem functions, such as through construction of water conveyance structures and channels that cross the Delta (Whipple et al. 2012). In some areas, limiting connectivity of waterways from such structures could improve ecosystem function (SFEI-ASC 2016). For example, closure of the Delta Cross Channel leaves additional flow in the mainstem Sacramento River and helps prevent entrainment of native fish species such as migration juvenile Chinook salmon.

The connectivity metric in this performance measure tracks the landscape in which physical dynamics, supported by geomorphic land-water interaction, can take place. This interaction requires two components: 1) physical or hydraulic connectivity that allows water to flow onto land; and 2) sufficient flow of water to inundate these connected areas (Merenlender and Matella 2013). Within the Delta, the terrestrial system has been largely disconnected from fluvial and tidal connectivity, even during periods of high flows. Restoring physical connectivity to the fluvial river and tidal system can help restore ecosystem processes and support many native species.

It should also be noted that hydrologic connectivity through surface waters can include more than floodplain areas. This is especially true in the Suisun Marsh and areas of the greater San Francisco Estuary. At this time this performance measure does not include areas such as riparian zones, because the focus is more on aquatic ecosystem functions in areas that can be inundated for extended periods and also due to limited habitat types within the Delta itself outside of floodplains or floodways. However, this could be explored further in the future, for example, by assessing the riparian area and upland transition zones, especially in Suisun Marsh (Goals Project 2015, Appendix E). While areas that function as riparian or intermittent floodplain are important, most of this habitat type is upstream or downstream of the Delta, where levees heavily constrain riparian function.

Inundation

Seasonal nontidal floodplain inundation is critical for providing a range of ecosystem benefits such as freeing and transformation of nutrients, increasing primary productivity, and creation of habitat that can serve as a migratory pathway, rearing habitat, and refuge for juvenile salmonids (Junk et al. 1989, Sommer et al. 2001b). Such areas promote wetland ecosystem functions and are a high-value area for rearing and spawning of fish species such as Sacramento splittail and Chinook salmon, leading to increased survival rates. Food production (phytoplankton and zooplankton biomass) requires sufficient duration of inundation to develop, thus food-web processes and habitat provision increase with duration of inundation (Sommer et al. 2001b, Moyle et al. 2008, Katz et al. 2017). Illustrative areas within or near the Delta include the Yolo Bypass, Sutter Bypass, agricultural and other vegetated lands that are regularly inundated, and areas of the Cosumnes River Preserve.

The hydrologically connected metric component tracks the area of land available to tidal and freshwater inundation, and the floodplain metric tracks nontidal, seasonal water surface area that inundates these connected areas.

Linkages to Delta Reform Act and the Coequal Goals

Delta Reform Act

The Delta Reform Act mandates that the Delta Plan include measures that promote specified characteristics of a healthy Delta ecosystem (Water Code section 85302(c)). Increased hydrologic connectivity and seasonal inundation of floodplains contribute to achieving “diverse and biologically appropriate habitats and ecosystem processes” (Water Code section 85302(c)(3)) and support “Conditions conducive to meeting or exceeding the goals in existing species recovery plans and state and federal goals with respect to doubling salmon populations” (Water Code section 85803(c)(5)).

Native resident and migratory fish species rely on habitat connectivity and floodplain inundation for their life cycle and the ecosystem functions they provide, aligning with “Viable populations of native and resident and migratory species” (Water Code section 85302(c)(1)). Restored land-water connectivity will provide diverse habitats and ecosystem processes such as primary production and energy transfer which supports “diverse and biologically appropriate habitats and ecosystem processes” (Water Code section 85302(c)(3)).

Delta Plan Core Strategy

4.2 Restore Ecosystem Function

Methods

Baseline Methods

Connectivity

Council staff developed a hydrologically connected spatial dataset by combining data for levee locations (to identify in-channel areas), bypasses, and floodways. Levee locations were compiled from multiple levee data sources, and from aerial imagery. Levee data sources included the following data sets. Data is listed in priority of use, with items first on the list being used in place of items later in the list when there is spatial overlap:

1. **DWR 2012:** i7 Delta Levee Centerline Classifications. Available online.
2. **URS 2007:** Delta Vision. Draft dataset provided by DWR and compiled by the consulting firm Arcadis in 2014 as part of the Council's Delta Levee Investment Strategy (DLIS) process. Not available online. DLIS feature class name: *DeltaVision_Levee_Reach_by_Hydro*
3. **DWR and URS 2007:** Delta Risk Management Strategy (DRMS) – Developed for DWR by URS Corporation in 2007; last updated 2013. Version used compiled by the consulting firm Arcadis in 2014 as part of the DLIS process. Not publicly available. DLIS feature class name: *levee_delta_centerlines_DRMS*
4. **Groves et al. 2019:** Decision Support Tool for the San Francisco Bay-Delta Levees Investment Strategy. Available online.
5. **DWR 2015:** Nonproject Levees. Part of a database intended to assist public agencies in assessing public safety needs for areas protected by levees. Compiled by the consulting firm Arcadis in 2014 as part of the DLIS process. Not publicly available. feature class name: *DWR_Levees_AllRDs*

Using the software program ArcGIS (version 10.4.1), these data were merged and clipped to the boundaries of the Delta and Suisun Marsh. Council staff removed areas when satellite imagery (NAIP 2016) indicated that the areas were unconnected, for example, when located on the landside of a levee. The connected areas were then compared to Global Surface Water Extent (GSWE) data to confirm if at least part of the contiguous area had been inundated at any point within the last 30 years. The baseline was then calculated as the entire hydrologically connected area, regardless of the area actually inundated during this period.

The hydrologically-connected area currently does not capture several tidal marsh areas. If and as restoration projects create newly connected tidal marsh areas in the future, these areas could be added in the future, and the entire layer updated.

Inundation

To calculate the baseline, the 1984-2018 GSWE data (Pekel et al. 2016) was used to identify areas that were inundated at least once every two years, but not inundated all of the time (i.e., inundation recurrence between 50 and 90 percent). The inundation dataset (GSWE, recurrence layer) was clipped to hydrologically connected surface areas within the Delta (Liberty Island was removed because it is now open water). For the baseline period for inundation, this analysis identified approximately 15,000 acres of inundated area matching these criteria. However, this represents a long-term average over more than 20 years. In addition, much of this area can be found within channel margins (bounded by levees) and along riparian areas/levee-water interfaces and is not limited to floodplains. Due to this and other limitations with the currently available data (see below), the baseline was set at approximately 15,000 acres as of the year 2018. This baseline date was selected to align with the period of data availability.

There are some limitations associated with the GSWE data. First, recurrence is calculated as a percentage of time that water appears at the same location from year to year. This means that an area could show 100 percent recurrence even if it is dry for periods of the year, and would be excluded by the less than 90 percent filter used in this analysis. Second, the GWSE appears not to include valid observations for the months of November, December, and January and this could affect the accuracy of the data. Third, there is no depth threshold for the inundation analysis since the data sources do not include this information.

Target Methods

Connectivity

The connectivity target is based on quantitative goals provided in the 2016 Central Valley Flood Protection Plan (CVFPP) Conservation Strategy, Appendix H (DWR 2016a, pp. H-4-6 to H-4-8) which identified numeric floodplain and tidal marsh area targets. These targets were based on the area modeled to help recover spring and fall-run Chinook salmon to meet the Central Valley Project Improvement Act (CVPIA) of 1992 salmon doubling goal. The area modeled to achieve this goal is reported in the 2016 CVFPP Conservation Strategy, Appendices H (DWR 2016a) and L (DWR 2016b) as follows: 11,000 acres for the Sacramento River Basin, and 4,500 acres for the lower San Joaquin River Basin. Analysis for the CVFPP identified that on average, only 17 percent of floodplains are considered suitable for salmonid species (DWR 2016a). To account for this, the areas required were divided by 17 percent to generate 64,705 acres needed for the Sacramento River Basin and 26,471 acres for the San Joaquin River Basin. Council staff then scaled these areas by the relative proportion of the Conservation Planning Areas (CPA) for the CVFPP within the Delta and Suisun Marsh as determined by a spatial analysis: approximately 52 percent of the Lower Sacramento CPA and 67 percent of the Lower San Joaquin CPA fall within this area. Multiplying by these respective factors (see equations below) results in 33,647 acres in the Lower Sacramento CPA and 17,735 acres in the Lower San Joaquin CPA, for a sum of 51,382 acres of floodplain habitat (see below). After rounding, the connectivity target is set to 51,000 acres. Here are the equations to set the targets:

- Sacramento CPA: 64,705 acres x 52% = 33,647 acres
- San Joaquin CPA: 26,471 acres x 67% = 17,735 acres

In addition to the connectivity approach described above, connectivity considerations are also illustrated in Appendix Q3, Figures 4-3 and 4-5.

Inundation

The 2016 CVFPP Conservation Strategy (Appendix H, p. H3-H7) calculated the amount of new floodplain needed in the Sacramento and San Joaquin watersheds to support doubling salmon populations, and it suggested that floodplains should be inundated in two-year intervals to support salmon life cycles (DWR 2016a). To calculate the area required for inundation targets, the connectivity target of 51,000 acres was proportionally split into nontidal (fluvial) and tidal areas based on estimation of historical habitats. San Francisco Estuary Institute’s (SFEI) historical ecology spatial data estimates 63 percent of the Delta as tidal, and 37 percent as nontidal (Whipple et al. 2012). Multiplying the nontidal estimate of 37 percent by the target of 51,000 acres of connectivity represents the floodplain inundation target of 19,000 acres (number rounded).

Data Sources

Primary Data Sources

The primary data sources listed below will be used for tracking this performance measure:

Connectivity

1. The Delta Stewardship Council Covered Actions Website. On-the-ground projects that restore surface water connectivity (such as levee breach, levee notch, weir modification, and tidal marsh restoration) are likely to meet the definition of a covered action and will need to establish consistency with the Delta Plan before implementation.
    a. Content: Covered actions' project description and supporting documentation provide details on project restoration activities and acres of land opened for hydrologic connectivity.
    b. Update Frequency: As covered actions are submitted and hydrologic connectivity is implemented.
2. San Francisco Estuary Institute (SFEI) Project Tracker. The Project Tracker is a tool that supports regional tracking of restoration projects and includes acres and locations of habitat types restored for hydrologic connectivity.
    a. Content: Project monitoring region wide.
    b. Update Frequency: As projects are implemented.

Inundation

1. GSWE from the European Commission Joint Research Center (JRC).
    a. Content: Global water surface areas (water extent, duration, and seasonality derived from remote sensing data).
    b. Update Frequency: Annually.

Alternative Data Sources

Alternative data sources will be used if the primary data sources become unavailable or are insufficient. Alternative data sources can be used concurrently with the primary data sources depending on best available science and the availability of the primary sources.

Connectivity

1. Two-dimensional hydrologic model and digital elevation model to identify the area that would physically allow fluvial or tidal surface water to flow onto land during events below the 1-in-100 recurrence interval flood flow, without pumping or modification of physical landforms. These areas may be dry in most conditions, but they could be hydrologically connected during high flows.

a. Content: Data to be developed based on two-dimensional hydrologic model (for example, SCHISM), high-resolution digital elevation model (based on 2017 or most up to date LiDAR-derived elevation).

b. Update Frequency: Updates are based on alternative methodology described above, when new elevation data or recurrence interval updates are available.

Inundation

1. Landsat Dynamic Surface Water Extent (DSWE) map. NASA makes available a Landsat-derived product that could be used to help monitor inundated surface water areas. Landsat satellite data has the longest historic record available and is anticipated to remain available far into the future with new satellite launches. However, because this is based on optical data it is affected by cloud cover and cloud shadow, making it less useful in winter months.

   a. Content: Estimate of surface water extent per pixel, derived from Landsat data and developed into interpreted layer of surface water extent.

   b. Update Frequency: Every 14 days; however, data may not be usable at this interval due to cloud cover.

2. National Aeronautics and Space Administration (NASA) and Indian Space Research Organisation (ISRO) Synethetic Aperature Radar (NiSAR) Mission. This mission will make active observations of surface water for at least three years, starting in early 2022. NiSAR data would help avoid an issue with the primary data source, where cloud cover affects imagery during periods of the year, limiting the ability to track inundation duration.

   a. Content: Data to be derived from imagery overlapping the Delta and Suisun Marsh.

   b. Update Frequency: Every 12 days.

3. European Space Agency SENTINEL Program. Sentinel-1 and Sentinel-2 platforms with combined overpass frequency of approximately every five days for a given location on Earth, including the Delta. Sentinel data would help avoid an issue with the primary data source, where cloud cover affects imagery during periods of the year. In addition, the update frequency of this dataset could allow for more accurate quantification of inundation duration. As part of this alternative, the duration of inundation (e.g., acre-days) could also be reported as supporting information.

   a. Content: Water surface extent, change, and seasonality derived from remote sensing data.

   b. Update Frequency: Approximately every five days. Sentinel water surface areas are anticipated to be incorporated into the base JRC GSWE data (Pekel 2019).

4. NASA Surface Water and Ocean Topography Mission (SWOT). Data from this mission should be available for at least three years after successful deployment and calibration, anticipated in 2022. The SWOT mission sensor includes the ability to measure water surface elevation. This means that it could be used to estimate water depth when used in conjunction with a known ground surface, such as LiDAR-derived terrain.

   a. Content: Water surface extent, elevation, change, and seasonality derived from remote sensing data.

   b. Update Frequency: Anticipate updates at a frequency equal to or better than 21 days.

Process

Data Collection and Analysis

Every year, Council staff will update the status of this performance measure by:

Connectivity

1. Reviewing Council Covered Actions website for projects that restore hydrologic connectivity (tidal marsh and floodplain restoration), and if necessary, contact project manager for clarifications on project status (construction status).
2. Adding project locations to the connected-land dataset and calculate acres open to hydrologic surface water connectivity.
3. Calculating annual change in hydrologically connected areas. Acres connected will be then calculated as the entire hydrologically connected area, regardless of the area actually inundated during this period.
4. If alternative or additional data sources are used, these sources will be disclosed on the Performance Measures Dashboard.

Inundation

1. GSWE data for surface water extent occurrence (primary data) will be downloaded in GeoTIFF format at~98 feet resolution (30 meters) in October of each year.

2. Data will be clipped to the boundaries of the Delta and Suisun Marsh, and converted to a projected coordinate system.
3. Council staff will analyze GSWE data primarily on the Google Earth Engine platform. Surface water area will be analyzed to determine maximum water extent during each water year (October 1 to September 31) for areas inundated 50-90 percent of the year.

Interim Performance Assessment

In order to provide a short-term assessment of progress toward the inundation and connectivity targets, intermediate milestones are set for evaluation every decade. The interim milestones are established on an assumed linear progression towards the 2050 target date:

Metric	Baseline (acres)	Total Area (Baseline Acres Plus Net Increase)		
		2030	2040	2050
Hydrologic Tidal and Fluvial Connectivity	75,000	92,000	109,000	126,000
Nontidal Inundation	15,000	21,400	27,700	34,000

Although linear progression is presumed for setting interim milestones, many management and environmental uncertainties exist, such as climate change and frequency of drought in implementing restoration projects and achieving the target acres of inundation and connectivity. Interim assessments of the performance measure will consider the existing state of the restoration in the Delta and disclose conditions impacting the rate of restoration interim progress.

Process Risks and Uncertainties

Assessments of the performance measure and the evaluation of interim milestones will account for issues within and outside of management actions and the long-term periods required to implement large-scale, on-the-ground projects.

Restoration of land-water connections to increase the areas with hydrologic connectivity that allow for increase in seasonal inundation depends on:

- Activities and effects within human management control (e.g., breaching or notching levees).
- Effects outside management control (e.g., peak flood flows, near- and medium-term sea level rise).

While areas outside of direct management control must be considered, the opportunities for reaching the target acreage require a concerted focus on modifications to the physical geometry of the Delta and Suisun Marsh.

Five-year averages will be used as interim milestones. However, a linear trajectory of annual acreage increases may not be a reasonable expectation. Rather, long lead times of restoration projects may cause a nonlinear increase in restored areas based on type and size of restoration projects completed.

Reporting

Reporting of this performance measure will include maps of connected areas and seasonally inundated areas, together with project locations that restore hydrologic surface water connectivity. Restoration project details will be displayed (e.g., year of restoration, type of connectivity restoration, acreages).

Every year, Council staff will report the status of this performance measure by:

1. Posting updates on the Performance Measures Dashboard.
2. Providing results in the Council's annual report (published in January).
3. Communicating management-relevant results at Council and Delta Plan Interagency Implementation Committee (DPIIC) public meetings.
4. Presenting findings at technical interagency groups, professional gatherings, and conferences.

Every five years, Council staff will assess and report the status of this performance measure by:

1. Communicating findings in the five-year review of the Delta Plan.
2. Informing the Council's adaptive management process and other decision-making.

Five-year averages will be used as interim milestones for assessments towards the target over the 30-year time period of 2020-2050 (i.e., every five years, to increase connected land by 8,500 acres and inundated areas by 3,000 acres).

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Performance Measure 4.16: Acres of Natural Communities Restored

Performance Measure (PM) Component Attributes

Type: Outcome Performance Measure

Description

Restoring large areas of natural communities to provide for habitat connectivity and crucial ecological processes, along with supporting viable populations of native species.

Expectations

Increase acres of natural communities to contribute to suitable habitat for fish and other wildlife, restored habitat connectivity, and viable populations of native species.

Metric

Acres of natural communities restored. This metric will be updated and evaluated every five years.

Baseline

Acres of natural communities from the 2007 Vegetation Classification and Mapping Program (VegCAMP) dataset by the California Department Fish and Wildlife (CDFW), as designated below:

Ecosystem Type	Baseline Acres (2007 VegCAMP)
Seasonal Wetland Wet Meadow Nontidal Wetland	5,100
Willow Riparian Scrub/Shrub Valley Foothill Riparian Willow Thicket	14,200
Tidal Wetland	19,900
Stabilized Interior Dune Vegetation	20
Oak Woodland	0
Grassland	33,000
Vernal Pool Complex	5,100
Alkali Seasonal Wetland Complex	700

Target

Net increase of target acres of natural communities by 2050:

Ecosystem Type	Target Acres Net Increase (from Baseline Acres)	Total Area (Baseline Acres Plus Net Increase)
Seasonal Wetland Wet Meadow Nontidal Wetland	19,000	24,100
Willow Riparian Scrub/Shrub Valley Foothill Riparian Willow Thicket	16,300	30,500
Tidal Wetland	32,500	52,400
Stabilized Interior Dune Vegetation	640	660
Oak Woodland	13,000	13,000
Grassland	No net loss	33,000
Vernal Pool Complex	670	5,770
Alkali Seasonal Wetland Complex	230	930

Basis for Selection

The wetland and riparian ecosystems of the Delta once supported productive food webs and rich arrays of native plant and animal species that contributed to exceptional biological diversity (Myers et al. 2000). Historically, the Delta and Suisun Marsh supported more than 650,000 acres of natural communities including riparian, wetland, and oak savanna. More than 90 percent of those ecosystems have been lost through reclamation and land conversion to agriculture and urban land uses (Bay Institute 1998, SFEI-ASC 2014). Reestablishment of some of these natural communities on the landscape—as the result of process-based restoration, improving ecosystem processes such as primary production and energy transfer—is a critical step in native species recovery. Natural community restoration will provide the physical space, connectivity, and habitat structure that species populations currently lack, as well as providing critical ecological functions such as aquatic primary production and vegetation community succession (Frermier et al. 2008, Golet et al. 2013). Multiple, interacting components of functional landscape will foster resilient and enduring restoration and management outcomes that benefit both people and wildlife (Wiens et al. 2016).

Recovery goals and biodiversity targets play a key role in translating ecological science and policy into on-the-ground action (Tear et al. 2005). Science-based objectives are often used to provide a unified understanding of conservation objectives among stakeholders and to make progress toward measurable goals (Dybala et al. 2017a, Dybala et al. 2017b). Recovery plans provide comprehensive guidance on the restoration and management of ecosystems based on the biology of the most threatened and endangered species (USFWS 2013).

Planning and management efforts, such as recovery plans, species-specific resiliency strategies, and conservation strategies identify specific actions for ecosystem preservation and restoration to meet species needs. Most of these efforts are focused on benefiting a single species or suite of similar species (e.g., riparian birds). Collectively, however, these plans provide valuable insight into the scale of ecosystem preservation, enhancement, and restoration necessary to benefit the multitude of species that rely upon the Delta ecosystem. At least 11 recovery and conservation plans exist which have geographic coverage in the Delta and Suisun Marsh (Council 2018). These plans identify restoration and management actions needed to achieve recovery of 35 species of special-status plants and 86 fish and wildlife species of conservation concern (Delta Plan, Appendix Q4). Nearly half of these species of conservation concern are endemic to the California floristic province, heightening the importance of recovering and conserving their populations in alignment with global conservation priorities (Wilson et al. 2006, Brum et al. 2017).

Restoration targets put forward by recovery and conservation plans are organized by the historical natural community types outlined in the Sacramento-San Joaquin Delta Historical Ecology Investigation: Exploring Pattern and Process (Whipple et al. 2012). The historical natural community types are classified by plant community structure and physical characteristics such as hydrology and landscape position. Modern habitat types use the same classification by plant communities (SFEI-ASC 2014). Importantly, the natural communities described in both Whipple (2012) and SFEI-ASC (2014) are derived from VegCAMP, which uses the U.S. National Vegetation Classification System to organize species assemblages (Hickson and Keeler-Wolf 2007).

Restoration of complex ecosystems will require reestablishment of native vegetation communities and the underlying processes that support their recruitment, disturbance regimes, and community succession (Fremier et al. 2008, Golet et al. 2013). Restoring a variety of native vegetation cover types can promote ecological resilience and enhance native biodiversity by providing a range of habitat options for species, thus expanding the types and numbers of species that a landscape can support (SFEI-ASC 2014, DSC 2018). It can take many years for a restored habitat to establish, and the trajectory of natural communities' evolution is dependent on site-specific conditions and external factors (Zedler and Callaway 1999, Lowe et al. 2014). Post-project monitoring, habitat assessments and scientific studies about restoration trajectories will inform ecosystem restoration management (Golet et al. 2013).

Linkages to Delta Reform Act and the Coequal Goals

Delta Reform Act

Large areas of natural communities provide functional, diverse and interconnected habitat suitable for fish and other wildlife, and support recovery of native species. Achieving the target net increase in acres of the natural communities will provide diverse and functional habitats that support the following characteristics of a healthy Delta ecosystem:

- "Viable populations of native and resident and migratory species" (Water Code section 85302(c)(1)). Native resident and migratory species rely on natural habitats for their life cycle and the ecosystem functions they provide.
- "Diverse and biologically appropriate habitats and ecosystem processes" (Water Code section 85302(c)(3)). Reestablishment of large areas of natural communities provides for recovery of diverse habitats and ecosystem processes such as primary production and energy transfer.
- "Reduced threats and stresses on the Delta Ecosystem" (Water Code section 85302(c)(4)). Large areas of restored natural communities support the capacity of native species to respond to changing environmental conditions.
- "Conditions conducive to meeting or exceeding the goals in existing species recovery plans and state and federal goals with respect to doubling salmon populations" (Water Code section 85302(c)(5)). Target acres for riparian, seasonal wetland, and emergent tidal marsh support rearing habitat needs for juvenile salmon, contributing to recovery of naturally spawning salmon populations.

Delta Plan Core Strategy

4.2 Restore Ecosystem Function.

Methods

Baseline Methods

The acreage of natural communities was derived from CDFW VegCAMP (2007) and by referencing the associated ecosystem types described in the 2016 Central Valley Flood Protection Plan (CVFPP) Conservation Strategy (DWR 2016a) and SFEI-ASC (2014). The VegCAMP dataset maps vegetation in the Delta from field observations and high-resolution digital imagery, and classifies the vegetation based on the U.S. National Vegetation Classification Standard (http://usnvc.org). Vegetation classification (e.g., pickleweed, broadleaf-cattail) from the VegCAMP was referenced to ecosystem types (e.g., alkali seasonal wetland complex, valley foothill riparian) found in SFEI-ASC (2014, Appendix A, pages 102 – 105).

Target Methods

Targets for each natural community (ecosystem) type were derived from conservation and restoration targets identified in conservation and recovery plans within the Delta and Suisun Marsh (Delta Plan, Appendix Q4). These conservation and recovery plans include overlapping actions (e.g., the CVFPP Giant Garter Snake Recovery Plan and Tidal Marsh Recovery Plan include targets for the tidal wetland ecosystem).

The table below shows net increase of target acres by ecosystem type, and associated recovery and/or conservation plans with source references provided. Targets from recovery and conservation plans with geographically larger footprints, such as the CVFPP Conservation Strategy (DWR 2016a, DWR 2016b), were proportionally calculated for the Delta and Suisun Marsh region.

Net Increase of Target Acres and Associated Source References

Ecosystem Type	Target Acres Net Increase (Net Increase from Baseline Acres)	Source Reference (Recovery and Conservation Plans)
Seasonal Wetland Wet Meadow Nontidal Wetland	19,000	Central Valley Flood Protection Plan (DWR 2016b)
Willow Riparian Scrub/Shrub Valley Foothill Riparian Willow Thicket	16,300	Central Valley Joint Venture Implementation Plan (Dybala et al. 2017b)
Tidal Wetland	32,500	Central Valley Flood Protection Plan (DWR 2016a, 2016b); Central Valley Flood Protection Plan (CVFPP 2017b); Giant Garter Snake Recovery Plan (USFWS 2017); Tidal Marsh Recovery Plan (USFWS 2013); Suisun Marsh Habitat Management Plan (USBR, USFWS, CDFW 2013)
Stabilized Interior Dune Vegetation	640	A Delta Transformed (SFEI-ASC 2014)
Oak Woodland	13,000	Central Valley Joint Venture Implementation Plan (DiGaudio et al. 2017b)
Grassland	No net loss[1]	A Delta Transformed (SFEI-ASC 2014)
Vernal Pool Complex	670	Conservation Measure 9, Bay Delta Conservation Plan (DWR 2013)
Alkali Seasonal Wetland Complex	230	Conservation Measure 9, Bay Delta Conservation Plan (DWR 2013)

Note:
[1] Currently there are more grasslands than historically; most of which are within the interior Delta that used to be freshwater emergent wetland (Whipple et al. 2012). Grassland on the Delta perimeter provides more natural functions in support of native species. Although the target is no net loss, more grasslands in the Delta perimeter is the goal.

The conservation and restoration targets for seasonal wetland, wet meadow, nontidal wetland, and tidal wetland are based on quantitative goals in the CVFPP Conservation Strategy (DWR 2016a, Appendix H, pg. H-4-6 to H-4-8). The CVFPP identified numeric targets for Central Valley floodplain and tidal marsh. Tidal Marsh targets identified in Giant Garter Snake Recovery Plan (USFWS 2017), Tidal Marsh Recovery Plan (USFWS 2013), Suisun Marsh Habitat Management Plan (USBR, USFWS, CDFW 2013), and Fish Restoration Program Agreement (DWR and DFW 2010) are included within the cumulative 32,500 target from the CVFPP. These targets were identified based on the modeled estimate of rearing habitat area required to help recover spring and fall-run Chinook salmon to meet the 1992 Central Valley Project Improvement Act salmon doubling goal. These Central Valley numeric target values were proportionally calculated for the Delta and Suisun Marsh (52 percent of the Lower Sacramento Conservation Planning Area and 67 percent of the Lower San Joaquin Conservation Planning Area fall within the Delta). The conservation targets of the willow riparian scrub/shrub, valley foothill riparian, and oak woodland types are based on population and habitat objectives for avian conservation in the Delta region of the Central Valley Joint Venture (Dybala et al. 2017b). The willow riparian scrub/shrub and valley foothill riparian target of 16,300 was proportionally scaled for the Delta from the Central Valley (27.62 percent in Delta out of the total Central Valley acres).

Data Sources

Primary Data Sources

1. VegCAMP. Delta Vegetation and Land Use [ds292]. Biogeographic Information and Observation System (BIOS). California Department of Fish and Wildlife.
   a. Content: The VegCAMP data set has taxonomy for vegetation that is then assigned to appropriate habitat types in the Delta.
   b. Update Frequency: Every five years. First update toto the VegCAMP dataset was released in 2019.
2. VegCAMP. Vegetation - Suisun Marsh [ds2676]. Biogeographic Information and Observation System (BIOS). California Department of Fish and Wildlife.
   a. Content: 2015 Suisun Marsh vegetation map.
   b. Update Frequency: Every five years.

Alternative Data Sources

Alternative data sources will be used if the primary data sources become unavailable or are insufficient. Alternative data sources can be used concurrently with the primary data sources depending on best available science and the availability of the primary source.

1. San Francisco Estuary Institute (SFEI). Bay-Delta EcoAtlas. Geographic Information System of wetland habitats, past and present.
   a. Content: EcoAtlas Project Tracker is a mapping tool for restoration projects and provides access to acres of habitat types to be restored by a project (Project Tracker).

- Update Frequency: Frequency of restoration project updates varies. Council staff will review EcoAtlas at least every five years for restoration project updates.

Process

Data Collection and Analysis

Every five years, Council staff will update the status of this performance measure by:

1. Obtaining the updated VegCAMP datasets (Delta Vegetation and Land Use, Vegetation – Suisun Marsh).
2. Categorizing VegCAMP Associated Native Vegetation Community type (VegCAMP CaCode) into associated natural communities (ecosystem types).
3. Calculating total acres by each of the natural communities and calculating net increase over the five-year period and against the baseline.
4. Displaying maps of natural communities in the Delta and Suisun Marsh, and displaying change over five-year period and against baseline.
5. Method and results will be provided on the Performance Measures Dashboard.

VegCAMP updates follow a consistent vegetation mapping and classification methodology. A VegCAMP update based on the 2016 National Agricultural Imagery Program dataset was completed in November 2019.

Interim Performance Assessment

In order to provide a short-term assessment of progress toward the restoration targets in this PM, intermediate milestones are set for evaluation every decade. The interim milestones below are established on an assumed linear progression toward the 2050 target date, and can be calculated as five-year averages (for example: the five-year average net increase for tidal wetland is about 5,500 acres), or ten-year averages:

Ecosystem Type	Baseline	Target Area (Baseline Acres Plus Net Increase)		
		2030	2040	2050
Seasonal Wetland Wet Meadow Nontidal Wetland	5,100	11,400	17,700	24,100
Willow Riparian Scrub/Shrub Valley Foothill Riparian Willow Thicket	14,200	19,600	25,100	30,500
Tidal Wetland	19,900	30,800	41,600	52,400
Stabilized Interior Dune Vegetation	20	240	450	660
Oak Woodland	0	4,400	8,700	13,000
Grassland	33,000	33,000	33,000	33,000
Vernal Pool Complex	5,100	5,300	5,500	5,700
Alkali Seasonal Wetland Complex	700	780	860	930

Although linear progression is assumed for setting interim milestones, many management and scientific uncertainties exist in implementing restoration projects and achieving the target acres of desired natural communities. Interim assessments of the performance measure will consider the existing state of restoration in the Delta and disclose conditions impacting the rate of restoration interim progress.

Existing efforts and tools evaluating restoration effectiveness and natural communities' conditions will be considered in interpreting this performance measure. These may include: Wetland Regional Monitoring Program (WRMP) and Habitat Development Curves for wetland and aquatic resources, Tidal Wetland Monitoring Framework for the Upper San Francisco Estuary for fisheries benefits, and project-specific long-term monitoring and operations plans.

Process Risks and Uncertainties

A linear increase in the net acres of natural communities may not be a reasonable expectation. Rather, longer-term restoration projects may cause nonlinear increase in restored areas based on type and size of restoration action completed. In addition, changes in natural communities in response to restoration actions may be nonlinear, discontinuous, abrupt, and have multiple trajectories. Scientific advances, emerging tools, effectiveness monitoring, and long-term monitoring of restoration areas will inform adaptive management of ecosystem restoration.

The Delta is subject to sea level rise, subsidence, and urbanization, all of which can constrain where and how much ecosystem restoration can be implemented compared to other conservation actions. It is uncertain whether restoration will be able to outpace sea level rise and rising temperatures associated with climate change.

Reporting

Every five years, Council staff will assess and report the status of this performance measure by:

1. Posting updates on the Performance Measures Dashboard.
2. Providing results in the Council's annual report (published in January).
3. Communicating findings in the five-year review of the Delta Plan.
4. Informing Council's adaptive management and other decision-making.
5. Communicating management-relevant results at Council and Delta Plan Interagency Implementation Committee (DPIIC) public meetings.
6. Presenting findings at technical interagency groups, professional gatherings, and conferences.

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