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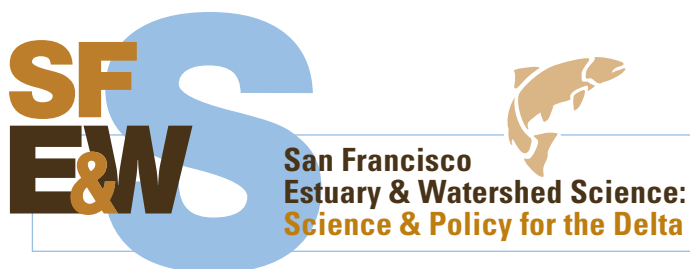
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## ESSAY

# Accounting for Water “Wasted to the Sea”

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## INTRODUCTION

Freshwater outflow from the Sacramento–San Joaquin Delta is a contentious management issue. Once mixed with salt water of San Francisco Bay, outflow is often characterized as having no value for urban and agricultural water supply, and thus “wasted to the sea.”

In the July issue of *San Francisco Estuary and Watershed Science*, Cloern et al. (2017) showed how outflow from the Delta provides multiple and diverse benefits to the San Francisco estuary. Rather than being “wasted,” this outflow improves ecosystem conditions and water quality, and reduces wastewater treatment costs.

The Cloern et al. (2017) essay highlights the importance of considering the multiple benefits of water as it moves within and out of the Delta. To do this, however, California needs a better water accounting system. In this report, we present an alternative approach. For the period 1980–2016, we assign inflow to the Delta to four categories:

1. Water used for diversions,
2. Outflow needed to meet salinity standards for diversions,
3. Outflow to meet ecosystem regulations, and
4. Water that results in outflow because of a lack of capacity for diversion.

This approach highlights that much of the outflow from the Delta – particularly during dry periods – achieves multiple economic and environmental benefits and is hardly “wasted to the sea.”

## **CURRENT ACCOUNTING FOR DELTA WATER**

The California Department of Water Resources (CDWR) is the Delta's official water accountant. CDWR summarizes the various uses of water in the state—including the Delta and the Sacramento and San Joaquin River watershed—to inform the California Water Plan, which is updated roughly every 5 years (CDWR 2013). CDWR divides water use—including applied water and net use—into three broad categories: urban, agricultural, and environmental. Within the Delta's watershed, net “environmental” water use includes: Delta outflow generated by water quality and flow regulations within the Delta (known as “required Delta outflow”); outflow generated by instream flow regulations upstream of the Delta; and outflow generated by rivers designated as “Wild and Scenic,” also upstream of the Delta.

CDWR's approach has important shortcomings. First, it does not distinguish between outflow used to maintain water quality for diversions and outflow required to protect ecosystems. Even if all regulations to support the Delta's aquatic ecosystem were removed, outflow would be needed to keep salinity low enough for in-Delta uses and for water exports by the Central Valley Project (CVP) and State Water Project (SWP). Failure to make this distinction fuels the perception that all environmental regulations in the Delta take water from other users and “waste it to the sea.”

Second, it is difficult to understand the data and methods used to apportion Delta outflow. This is most evident in CDWR's accounting of both the additional outflow generated when total inflows into the Delta exceed water diversion capacity or demand and the outflow required by environmental regulations. This additional outflow—which occurs in even the most severe droughts—is an essential and integral part of water management in the Delta because it reduces salinity, which in turn reduces the need to release water from reservoirs upstream of the CVP and SWP to maintain water quality. This is another important and often under-appreciated benefit of water “wasted to the sea.” But CDWR's accounts do not systematically track this outflow, and the methods of apportioning counted outflows are not easily understood. (For example, CDWR designates a large portion of flows in upstream segments of Wild and Scenic rivers in the San Joaquin Valley as environmental water use, even though these river segments flow into reservoirs used for downstream water supply.)

Finally, CDWR's accounting system is not timely. The latest water plan update (CDWR 2013) includes data through 2010. Long lags make it difficult to use these data to guide management or inform public debate.

## **AN ALTERNATIVE ACCOUNTING APPROACH**

We recommend an alternative approach to accounting for water use in the Delta. This approach—described in Gartrell et al. (2017)—is more detailed, yet easy to develop and understand, which makes it more useful for decision-making even as it fosters a common understanding of Delta water use.

In this framework, water that flows into the Delta from upstream tributaries is assigned to four broad categories of use:

1. **Water Diversions:** water diverted by farms and communities within and surrounding the Delta (“in-Delta use”) or water exported by the C. W. “Bill” Jones (Jones) pumping plant at the CVP and the Harvey O. Banks (Banks) pumping plant at the SWP (“Delta exports”).
2. **System Water:** outflow required to meet salinity standards for in-Delta water users and exports. The State Water Resources Control Board (SWRCB) has set a range of salinity standards for agricultural, municipal, and industrial uses of Delta water through its water quality control plans (Decision 1485 [D-1485] from 1978 to 1995, and Decision 1641 [D-1641] from 1995 to the present), including export uses. These salinity standards have remained unchanged since first promulgated in 1978. The CVP and SWP have assumed responsibility for meeting these standards through releases of water from upstream reservoirs and changes in the timing and volume of export pumping.
3. **Ecosystem Water:** outflow required in addition to system water to meet federal and state regulatory standards for fish and wildlife. Because some outflow would be required to meet water quality for in-Delta diversions and exports regardless of whether these laws were in effect, we count ecosystem water as the incremental outflow required above system water. The regulatory standards are varied and overlapping, and they have changed significantly over time (see appendices A and B in Gartrell et al. 2017). The most important ecosystem water requirements come from the SWRCB’s Delta water quality control plans, and the biological opinions issued under the federal Endangered Species Act (ESA). These regulations create outflow in three ways: (1) by setting flow standards for inflow to the Delta and the portion that must result in outflow to support habitat; (2) by setting salinity standards for habitat that requires outflow above system water (the “X2” salinity standard is an example); and (3) by restricting the timing and volume of export pumping, which can result in additional Delta outflow. As with system water, the CVP and SWP are responsible for meeting ecosystem water requirements.
4. **Uncaptured Water:** outflow in excess of system and ecosystem water. Uncaptured water occurs most commonly during periods of high runoff after winter storms or during high snowmelt years. It is most abundant in wet years, when it comprises the majority of Delta outflow, but it occurs in all water year types.

We used multiple data sources along with salinity models to assign inflow to the four categories for the period 1980–2016 on a daily basis, and then aggregated the results on a monthly and annual basis. The details of this approach – including spreadsheet summaries of data, calculations, and assumptions – are available in Gartrell et al. (2017) and are summarized in [Table 1](#).

**Table 1** Methods used to calculate apportioned Delta inflow<sup>a</sup>

Category	Definition	Data Sources and Calculations
Delta diversions	Water diverted for project exports and agricultural, municipal, and industrial (M&I) uses in and around the Delta	Sum of the following two sub categories.
In-Delta use	Consumptive use of inflow through evaporation, seepage, and diversions for irrigation of Delta farms. Precipitation is subtracted from this. Includes diversions for Contra Costa Water District and North Bay Aqueduct.	In-Delta use based on CDWR estimates of Delta island diversions and return flows (CDWR 1995). All other calculations based on data in CDWR's California Data Exchange Center (CDEC) and CDWR's Dayflow records.
Delta exports	Diversions from the Jones and Banks pumping plants for the CVP and SWP.	Dayflow, CDEC
System water	Outflow needed to meet salinity standards for in-Delta uses and exports.	Sum of the following two sub categories.
Export water quality	Outflow needed to maintain water quality at the Jones and Banks pumping plants in the south Delta.	Determined through G-Model relationships between outflow history and salinity (Denton 1993).
Agricultural, municipal, and industrial (M&I) standards	Outflow needed to meet M&I and agricultural water quality standards at various locations in the Delta. Standards vary throughout the year.	Determined through G-model relationships at multiple locations. Whichever is higher is used as the requirement for that day.
Ecosystem water	Outflow needed to meet salinity or flow standards for ecosystem regulations, or outflow generated by pumping restrictions.	Sum of the following two sub categories.
Ecosystem flows	Outflow required by regulation to meet habitat needs.	Outflow value prescribed by regulation above system water.
Ecosystem water quality	Outflow necessary to meet water quality standards for habitat. "X2" salinity standards vary throughout the year and between year types.	Determined through G-Model relationships. Value is amount above system water and ecosystem flows.
Export pumping limits	Inflow that is potentially available for pumping at Banks and Jones pumping plants but is allowed to become outflow as a result of pumping limits. Varies throughout the year.	Calculated based on total restrictions prescribed in D-1485, D-1641, CVPIA, VAMP, and ESA biological opinions.
Uncaptured water	Outflow greater than required for system and ecosystem water.	Dayflow, CDEC, and CDWR (1995) used to estimate total daily outflow; uncaptured volume determined by subtracting system and ecosystem water.

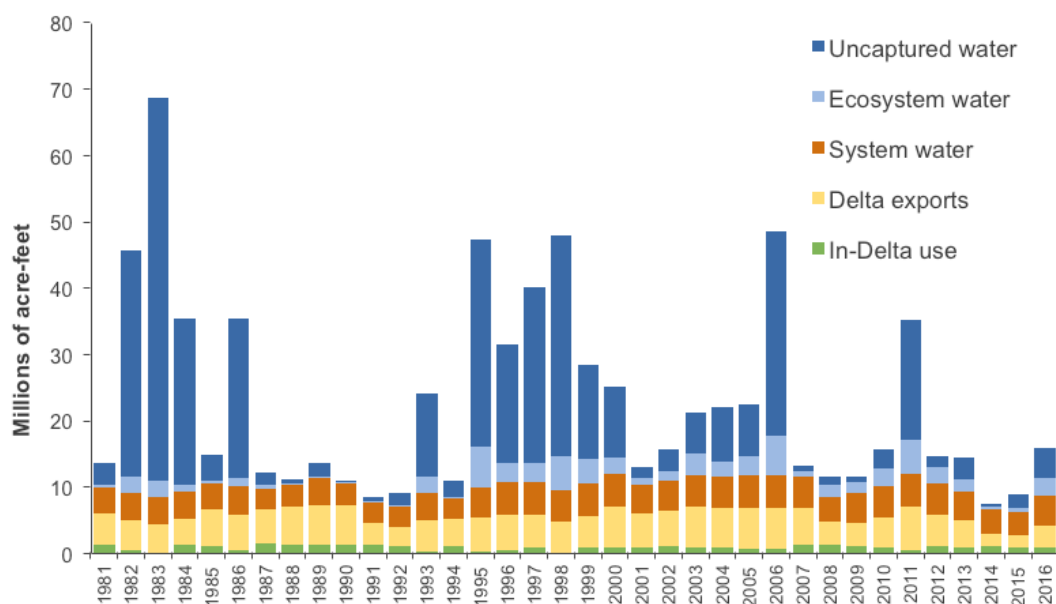
a. A complete description of assumptions and accompanying data is found in Gartrell et al. (2017).

Salinity conditions in the Delta are a function of many factors, including inflow, pumping, current and historic outflow, winds, tides, and the opening and closing of the Delta Cross Channel (Monismith 2016). Thus, multiple combinations can lead to the same salinity. In addition, there are important uncertainties about current tools to estimate daily outflow from the Delta (Bureau et al. 2016). Given these complexities, calculations for a given day are likely to exhibit considerable uncertainty, and should not be used for precise evaluation. However, these complexities likely average out over time to give a reasonable estimate of outflow and salinity relationships over the course of months.

## RESULTS

The approach used here provides a more useful representation of the fate of inflow to the Delta. A time-series of water years 1981 through 2016 is presented in Figure 1. This captures the extreme variation in amount of inflow to the Delta, and variation in apportionment of water between different year types and changing environmental regulations. Based on this, there are three key conclusions and one important caveat about these results:

- System water volume is large and increasing,
- Ecosystem and uncaptured water varies by water year,
- Ecosystem water has increased, and
- Increases in system and ecosystem water do not equal decreases in export volumes in all years.



**Figure 1** Assignment of Delta inflows among various uses during the hydrologic water year (October 1 to September 30). Source: Gartrell et al. (2017).

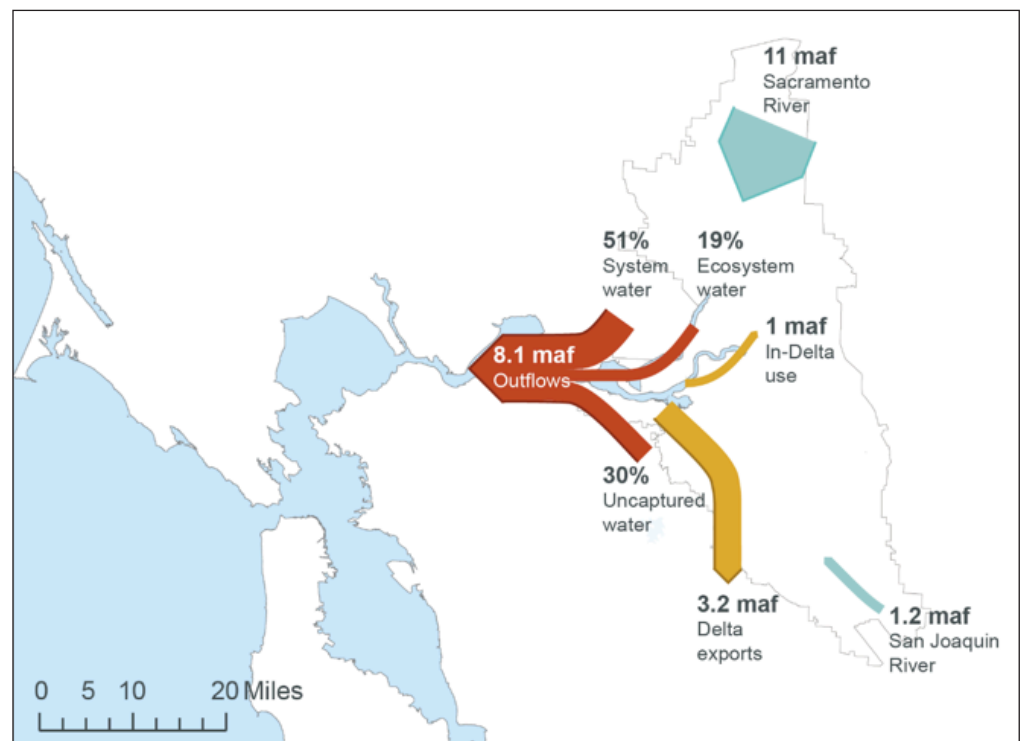
### System Water Volume is Large and Increasing

Water that CDWR assigns to the environment as “required Delta outflow” achieves both water supply and Delta ecosystem objectives. Since 1995, an annual average of roughly 4.5 million acre-feet (maf) of this outflow is system water, needed to maintain salinity for diversions by farms and communities in and near the Delta and the export projects. In addition, the amount of water needed to meet these salinity standards has grown by 0.4 to 0.6 maf per year since the mid-1990s, even though the standards themselves have not changed.

This increase in outflow to maintain salinity standards has put greater pressure on CVP and SWP reservoirs to maintain water quality in the Delta. The causes of this increase in needed outflow has not been well-documented but it is potentially the result of channel dredging, installation of operable gates, changes in operations, or possibly the use of a larger database to calibrate salinity models.

### Ecosystem and Uncaptured Water Varies by Water Year

Although system water remains relatively consistent from year to year, ecosystem water and uncaptured water varies with the magnitude of Delta inflows. In wet years, uncaptured outflow is large because of the abundance of runoff into the Delta. Ecosystem outflows are also relatively large in wetter years, when water quality control plans and biological opinions increase the share of Delta inflow assigned to meet ecosystem needs. Conversely, the share of ecosystem water in dry years is relatively small, especially compared to system water. Figure 2 illustrates this for the recent drought (water years 2012–2016), when average ecosystem water accounted for less than 19% of Delta outflow—versus 51% for system water. In 2015, the driest year of the drought, ecosystem outflow accounted for less than 7% of total outflow. This finding runs counter to one of the popular narratives of the drought, which asserted that environmental regulations led to high outflows to protect endangered fish.



**Figure 2** Apportionment of Delta inflow during the 2012–2016 drought. Volumes and proportions based on averages of 5 water years. Inflow does not equal diversions plus outflow because of rounding. Source: Summary of data in Figure 1 and Gartrell et al. (2017).

### **Ecosystem Water Has Increased**

Although there are misperceptions about the role of environmental regulations in Delta outflow, there have been significant increases in the volume of water assigned to ecosystems, with substantial costs to water exports. The first significant increase was in 1995 after the Bay–Delta Accord (later formalized in D–1641). The new standards increased flow requirements and strengthened salinity standards to support endangered fishes. Other programs such as the Vernalis Adaptive Management Program (VAMP) and Central Valley Project Improvement Act (CVPIA) added to ecosystem outflows (see summary in Gartrell et al. 2017).

The second major increase followed the 2008 updates of the biological opinions for several ESA-listed native fishes, which placed more stringent restrictions on export pumping operations. Comparing the period before D–1641 to current regulations (post-2008 biological opinions), roughly 0.9 maf additional ecosystem water is required during critically dry years, and as much as 2.7 maf additional ecosystem water is required during wetter years.

### **Increases in System and Ecosystem Water Do Not Equal Decreases in Export Volumes in All Years**

It is important to note that increases in system and ecosystem outflow do not result in equivalent decreases in export water supply. Especially in wetter years, uncaptured flow plays a critical role in improving Delta salinity and reducing the need to release water from reservoirs or reduce pumping to maintain water quality or flows for ecosystems. In addition, project operators can often limit the effects of regulations on exports—including those that restrict pumping—by shifting the timing of exports to periods when regulations are less restrictive. However, during dry years, when water is managed more tightly and there is limited uncaptured flow, the volume of system and ecosystem water is likely close to a true cost to water supply operations. Since the late 2000s, in many years the effect of ecosystem regulations has grown, as export pumping limits have increased and become more restrictive. In Gartrell et al. (2017), we compare our results with a commonly used simulation of the cost of increased regulations to water exports (MBK Engineers and HDR 2013) and find that our results are broadly consistent with effects on exports during dry years.

### **CONCLUSION**

The state’s current approach to accounting for Delta water is not sufficiently detailed, easy to use, or timely, and it does not adequately capture the benefits of Delta outflow for water users or ecosystem benefits. We recommend that CDWR and other agencies adopt a new approach to accounting that can form the basis for a common understanding of the uses of Delta water. This involves disaggregating what CDWR calls “required Delta outflow” from system water and ecosystem water. It also includes tracking uncaptured water, which plays an important—and often under-appreciated—role in meeting both water supply



and ecosystem water quality objectives. These changes will help in efforts to manage the Delta and to monitor the effect of hydrodynamic changes on water management—whether from changing inflow, configuration of the Delta, or rising sea level.

Our effort—accomplished with limited staff resources using publicly available data and models—also shows that this can be done in a more timely manner than through the generation of water plan updates. This approach can improve stakeholders' understanding of Delta water and help decision-makers. It also can spark the beginning of a discussion about developing an ecosystem water budget to improve water management in this region (Mount et al. 2017).

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