# THE SALTON SEA AND THE QUANTIFICATION SETTLEMENT AGREEMENT

GIS in Water Resources


**PREPARED BY**

Madison Rasmus


DECEMBER 8, 2017

# Table of Contents

## FIGURES



## TABLES

# 1 Introduction

## 1.1 BACKGROUND

The Salton Sea is not hard to spot a California map. As the largest body of water in the state it stands out in the arid, desert Imperial Valley of Southern California. Any California resident is probably familiar with, or has at least heard of, the Salton Sea, but what many people may not know is that its creation was a total accident. In 1907, an accidental breach of a canal diverting water from the Colorado River, caused 18 months of continuous flooding into the Salton Basin [4]. While it was assumed the Sea would simply dry up as it had done in the past, a continuous supply of agricultural runoff from farms in the surrounding Imperial and Coachella Valleys have kept the Salton Sea at a relatively consistent size. For decades the Salton Sea thrived as a desert oasis for vacation goers and celebrities alike, making it the most popular state park in California. In recent times, however, the Salton Sea has been plagued with a wide range of environmental issues, threatening both the wildlife and human populations inhabiting the area.


Figure 1. Salton Sea location map

In 2003 the Quantification Settlement Agreement (QSA) was reached between the Imperial Irrigation District (IID), the San Diego County Water Authority (SDCWA), the Metropolitan Water District (MWD) and several other smaller water agencies [3] The primary objective of the QSA was to reduce California's over-dependence on Colorado River water while also making more water available for urban use. To accomplish this, irrigation water conservation efforts have been undertaken by the IID, providing farmers with financial incentives to either fallow their fields or install improved irrigation technologies [5]. In exchange for this conservation, the IID is able to transfer additional water to more urban areas in nearby San Diego, Orange, Los Angeles, and Riverside Counties via the SDCWA and MWD.

Because the agricultural water usage is declining, the inflows to the Salton Sea are also declining, causing the volume of the Sea to shrink. This is a serious public health concern because this exposes toxic lake bed, which can spread harmful dust and fine particles throughout Southern California. In fact, Imperial County already has the highest rate of asthma-related emergency room visits in California, due to the high amount of dust already coming from these exposed lake beds [1]. To mitigate this issue, the IID is required to provide makeup water to the Salton Sea to keep the inflows as consistent as possible. However, this term of the QSA is only valid until the end of 2017, after which inflows to the Salton Sea are expected to decrease dramatically. The California government is considering a variety of options for long-term mitigation measures for the Salton Sea, but it is important to quantify the current situation understand the impacts after the makeup waters halt.

## 1.2 PROJECT OBJECTIVES

While surprisingly limited data for the Salton Sea area is available to the public, the primary objective of this project is to employ GIS to understand the current status of Salton Sea inflows via agricultural runoff and how this may change after IID makeup waters stop at the end of this year. In addition, this project also seeks to understand how implementation of the QSA in 2003 has impacted agricultural and municipal water usage in Southern California.

# 2 Methodology and Data Analysis

## 2.1 SALTON SEA WATERSHED AND FLOWLINE DEVELOPMENT

The Salton Sea takes in agricultural runoff from all over inland Southern California. The watershed and flowlines were developed for the Salton Sea watershed to get a better understanding of inflow sources. The following sections describe the methodology and data analysis.

### 2.1.1 Methodology

The NDHPlus dataset was pulled from the ArcGIS Living Atlas containing flowlines and catchments. The HUC12 watersheds near the Salton Sea were filtered by the HUC8 ID (18100204) to generate the resulting Salton Sea HUC8 Watershed. The flowlines were then clipped to fit this watershed. The main rivers in the subbasin, the New River and the Alamo River, were extracted from the clipped flowline layer via a query by GNIS Name.

Stream gage data from USGS was utilized to examine average annual flow at points along the New and Alamo Rivers. Coordinates of the selected gages were input into the GIS file via an Excel .csv file.

### 2.1.2 Data Analysis

Figure 2, below, shows the resulting HUC8 watershed as well as the New and Alamo Rivers.

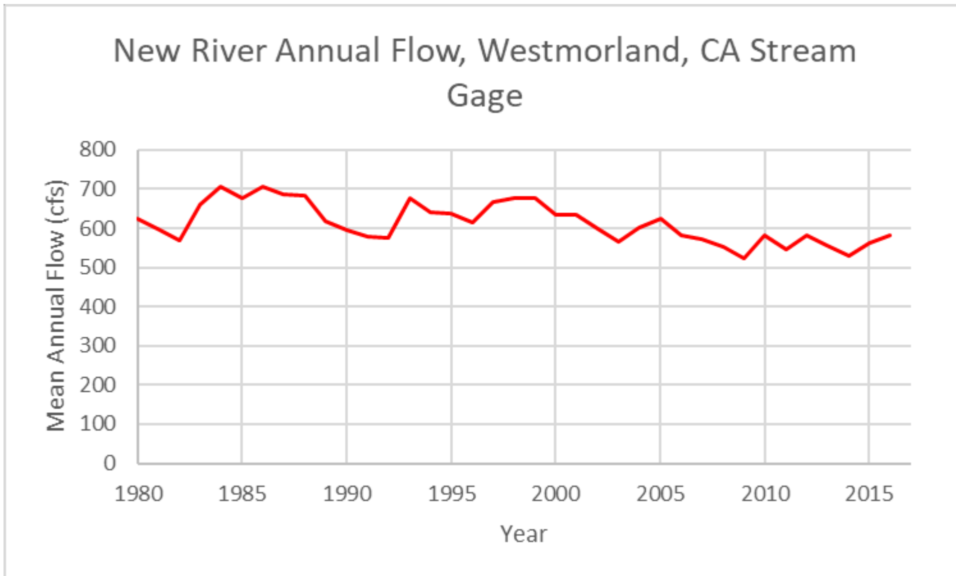

Figure 2. Salton Sea HUC8 watershed and main inflows

The Salton Sea HUC8 watershed is over 500 mi$^2$, encompassing a majority of Imperial County, a large portion of Riverside County, a small portion of San Diego County, and a part of Mexico . The New and Alamo Rivers (identified in Figure 3), flow south to north into the Salton Sea, picking up agricultural drainage from the Imperial County farms. It is important to note that while the figure appears to show the stream abruptly ending at the US-Mexico border, the streams originate in Mexico, though these flowlines are not included in the NHDPlus dataset.

Figure 3, shows the USGS stream gage locations that were analyzed for the New and Alamo Rivers. The New and Alamo Rivers are fed nearly entirely by agricultural runoff in the Imperial Valley and Mexico. They make up a majority of the inflows to the Salton Sea and are considered among the most polluted waterways in the United States [1].


Figure 3. USGS stream gage locations (color coded)

USGS maintains two active stream gages for the New River and one active stream gage for the Alamo River. For comparative purposes, data from another Alamo River stream gage that was maintained until 2002 was also collected [7]. The plots below show the average annual flow in cubic feet per second (cfs) for each stream gage. For ease of visualization, the plots are color coded to match the stream gage colors shown on the map in Figure 3.



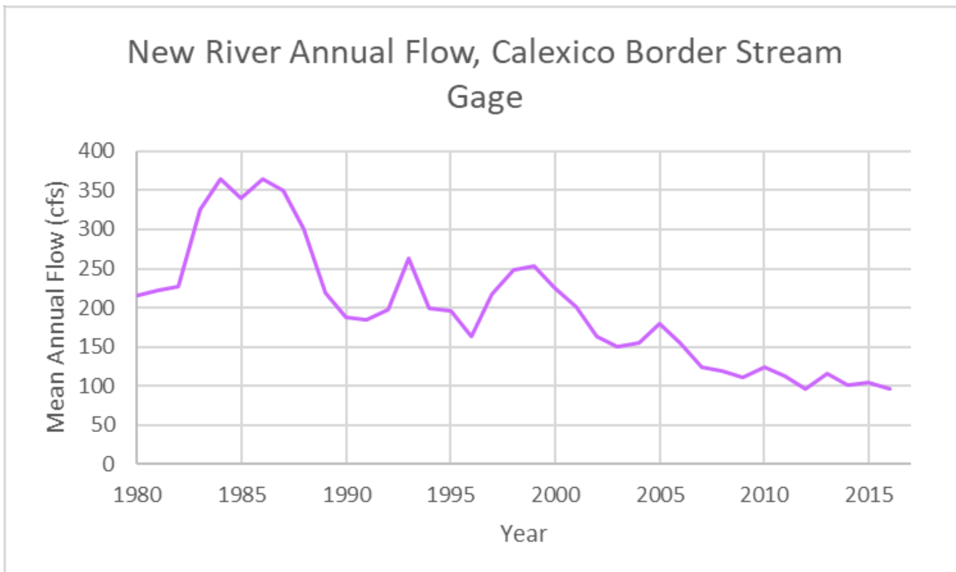
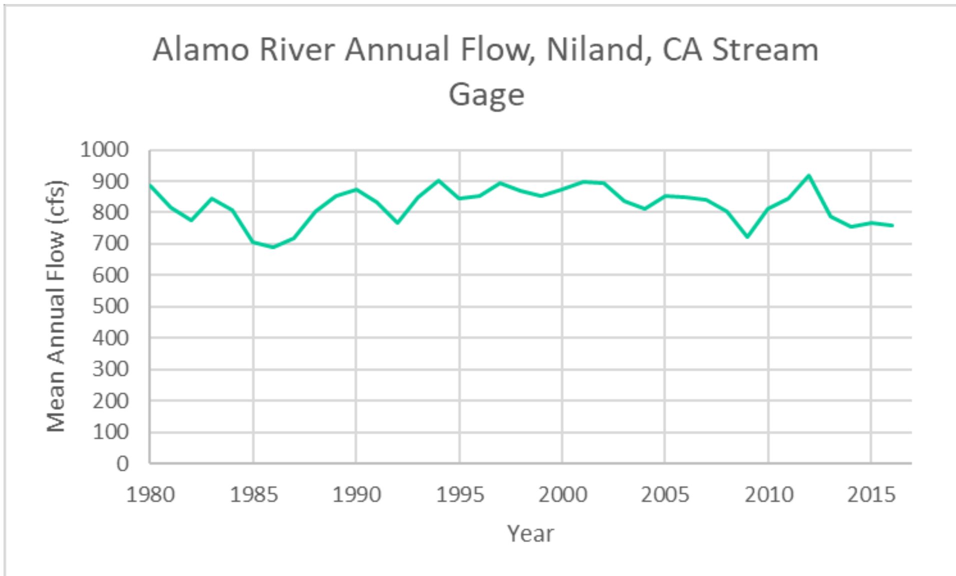




Figure 4. New River mean annual flows by stream gage

While the Calexico Border stream gage shows an overall declining trend in flows from 1980-2016, the Westmorland stream gage remains consistent over the same time period. The Westmorland gage is nearly at the inlet to the Salton Sea, so it can be assumed the overall inflow rate has remained relatively constant at approximately 613 cfs. The decrease in flows shown at the Calexico Border stream gage could be attributed to less agricultural runoff coming from Mexico.



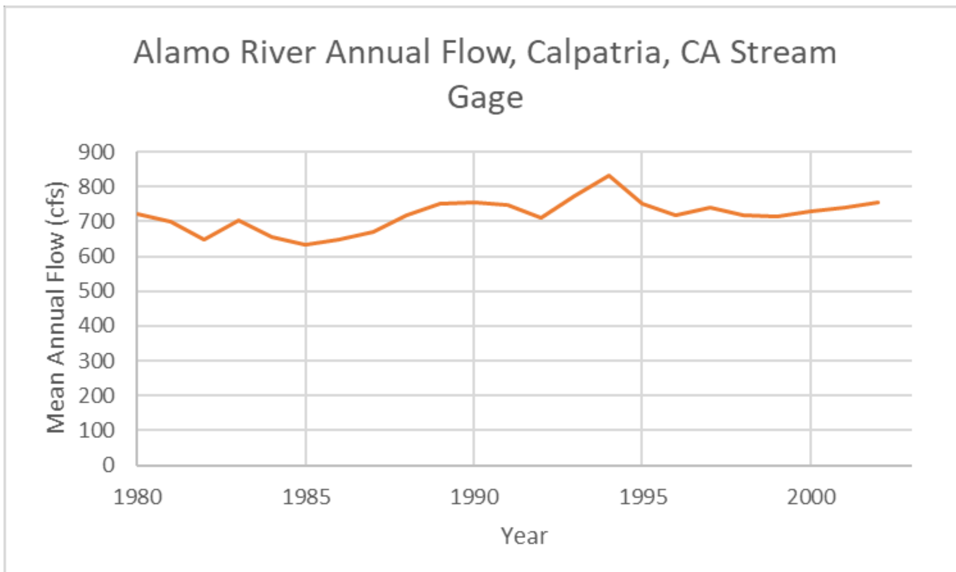




Figure 5. Alamo River mean annual flows by stream gage

While the Calpatria stream gage only has data from 1980-2002, both stream gages show consistent inflow rates for their respective time frames. Similar to the New River, the Niland, CA gage is near the inlet to the Salton Sea, indicating that inflows via the New River have also remained consistent at an average of 823 cfs.

Looking only at the USGS stream gage data it seems counterintuitive that inflows via the New and Alamo Rivers remain consistent despite the effort by the IID to reduce agricultural water usage. Figure 6 below shows the annual makeup water (in acre-feet per year) that has been supplied to the Salton Sea by the IID since the initiation of the QSA in 2003 [2].

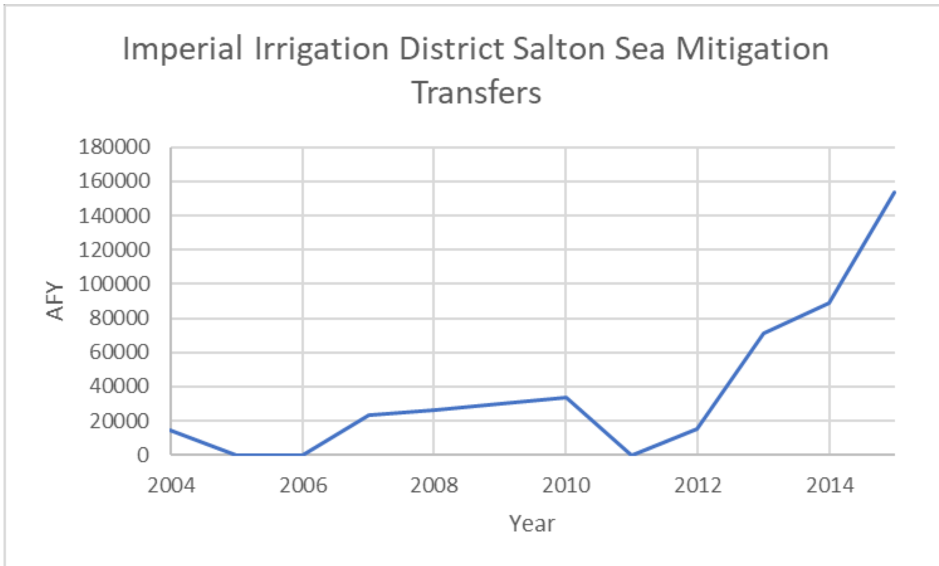



Figure 6. IID annual Salton Sea mitigation water

Data was available from 2003-2015 for annual water transfers to the Salton Sea via the IID. In recent years, the amount of mitigation water has increased dramatically, likely due to a combination of statewide drought conditions and increased irrigation water conservation efforts. These transfers help maintain the steady inflow levels that have been observed on the Alamo and New River stream gages. While it would be beneficial to have access to the 2016 and, ultimately, 2017 mitigation transfer data, the data shown indicates that the end of IID transfers will be detrimental to the Salton Sea volume.

## 2.2 SOUTHERN CALIFORINA WATER USAGE

Trends in Southern California water use were analyzed to understand how implementation of the QSA has impacted both agricultural and municipal use each county. Data was analyzed from 2000-2010 to quantify water usage before and after QSA implementation.

### 2.2.1 Methodology

Boundary files for the California counties were acquired via the ArcGIS Living Atlas. The shape for the California state was derived by using the dissolve tool on the county shapefile. San Diego, Imperial, Orange, Riverside, and Los Angeles counties were extracted to compare water usage trends between them.

Water data usage by county was obtained from USGS [7]. Data is available in five-year increments from 1985-2010 in Excel file format. Water usage in the USGS dataset is broken down into different categories such as irrigation, industrial, domestic, public supply, thermoelectric, and aquaculture. Usage data for the applicable Southern California counties was exported into a .csv file. The data was then added to the county shapefile via the “join” function.

### 2.2.2 Data Analysis

The total irrigation and public supply water usage for San Diego, Imperial, Orange, Riverside, and Los Angeles counties were examined in 2000, 2005, and 2010. Public supply usage is the total domestic and municipal water use and irrigation usage encompasses crops and livestock. Figure 7 and Figure 8 show the total public supply water usage and irrigation water usage respectively in these counties in the years 2000 and 2010. The data in the year 2000 is representative of the water usage in the region prior to implementation of the QSA while the year 2010 is representative of regional water usage well after implementation of the QSA.

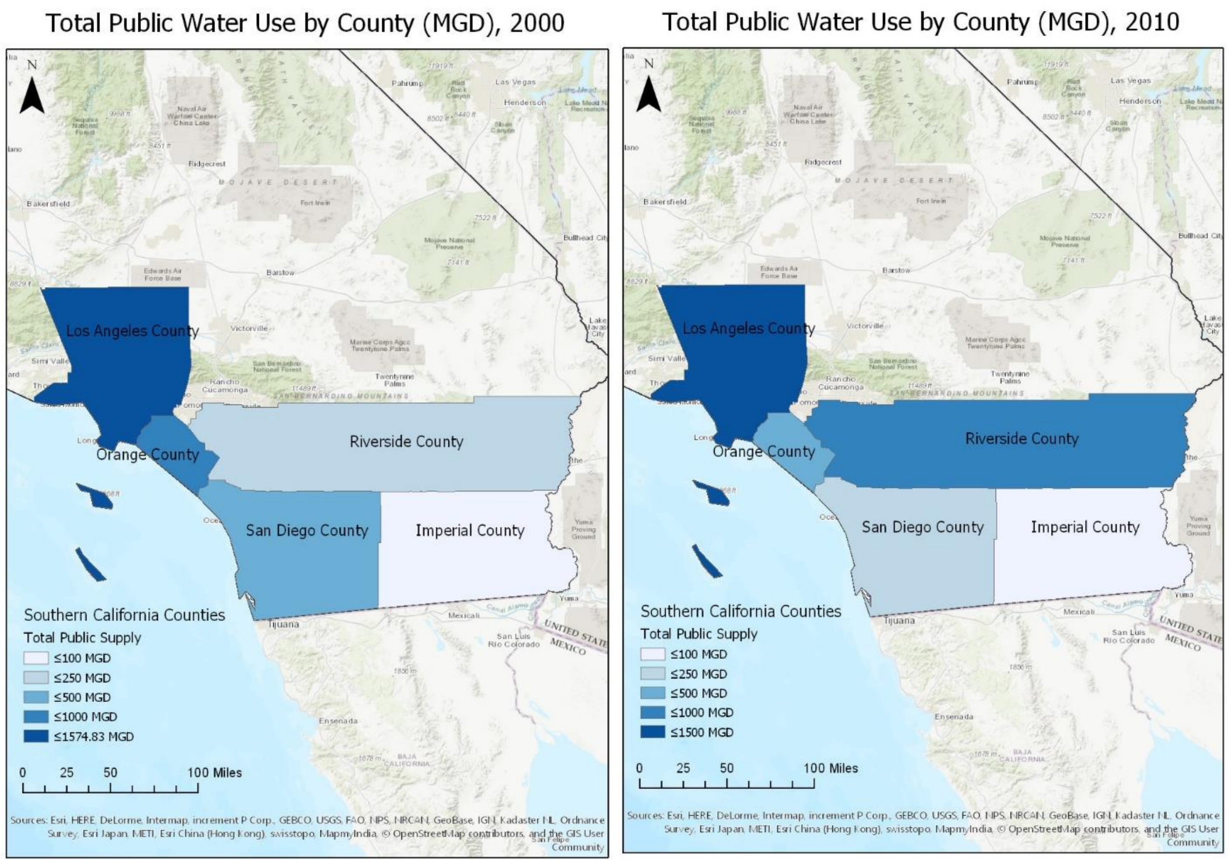



Figure 7. Public water usage by county, 2000 vs. 2010

In the year 2000, public water usage is largest in San Diego, Orange, and Los Angeles Counties, the most populace counties in Southern California. Imperial and Riverside Counties, the more agricultural based counties have a comparably low public water usage. In 2010, however, we can see a slight decline in public water usage amongst the coastal counties and a sharp increase in Riverside County. Correlating this to population sizes, available below in Table 1, we can see that Riverside County experienced the largest percent population increase amongst the five counties, increasing by over 40% [6]. The coastal counties, comparably, experienced far less population growth. Public water usage losses amongst these counties in 2010 are likely contributed to increased conservation efforts due to the California drought as well as less volatile population sizes. The data from 2015 is not yet publicly available via USGS, but would be a useful data point to understand the water usage in California as the state recovers from the recent drought.

Table 1. US Census data for Southern California Counties

| County | Total Population, 2000 | Total Population, 2010 | Percent Increase |
|---|---|---|---|
| San Diego | 2,813,833 | 3,095,313 | 10.0% |
| Imperial | 142,361 | 174,528 | 22.6% |
| Orange | 2,846,289 | 3,010,232 | 5.8% |
| Riverside | 1,545,837 | 2,189,641 | 41.6% |
| Los Angeles | 9,519,338 | 9,818,605 | 3.1% |

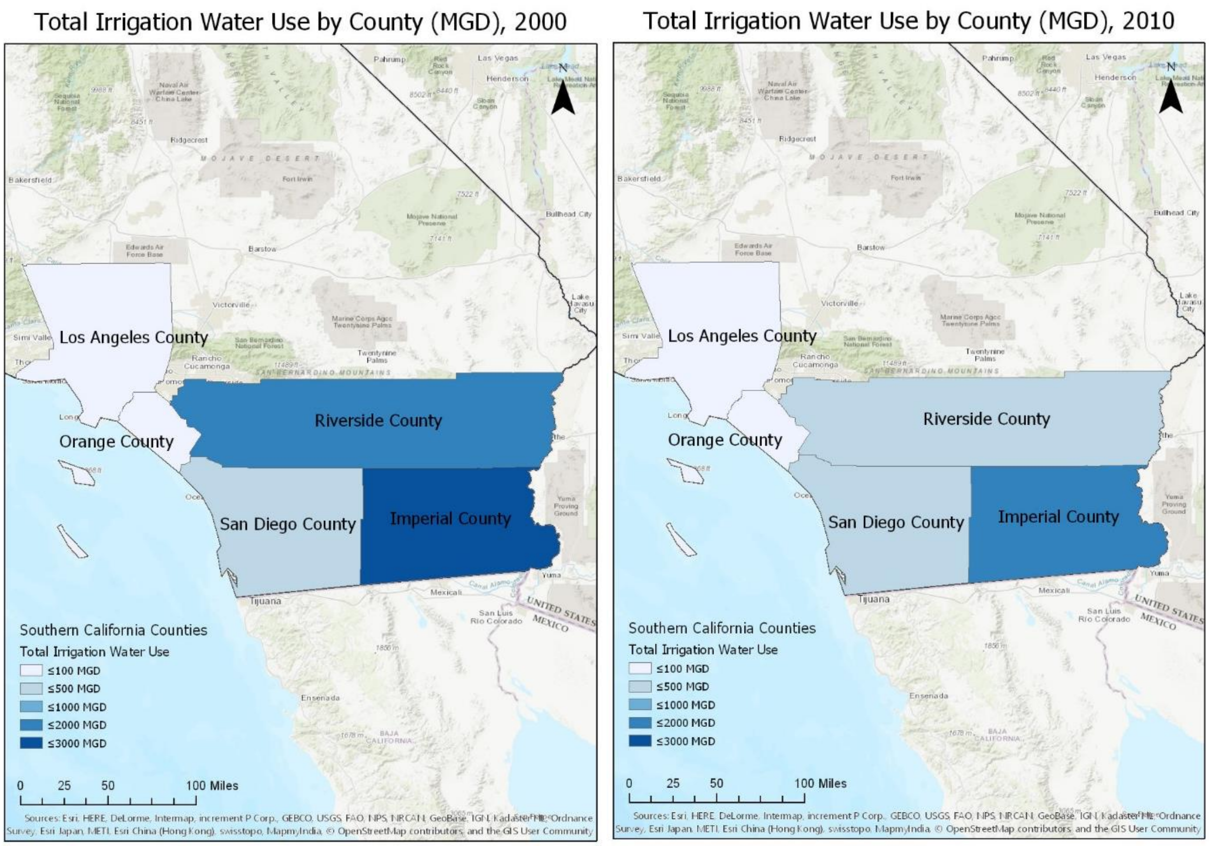



Figure 8. Irrigation water usage by county, 2000 vs. 2010

Irrigation water usage in Imperial and Riverside Counties is significantly larger than the coastal counties in the year 2000. In the year 2010, the irrigation usage remains comparably high for Imperial County compared with the other counties. There is a significant decrease in irrigation usage seen in both Imperial and Riverside Counties. The decrease in Riverside County can likely be attributed to the sharp rise in population and development of formerly agricultural land. The plot below in Figure 9 displays a quantitative look at the change in irrigation water usage from 2000-2010 in five-year increments.

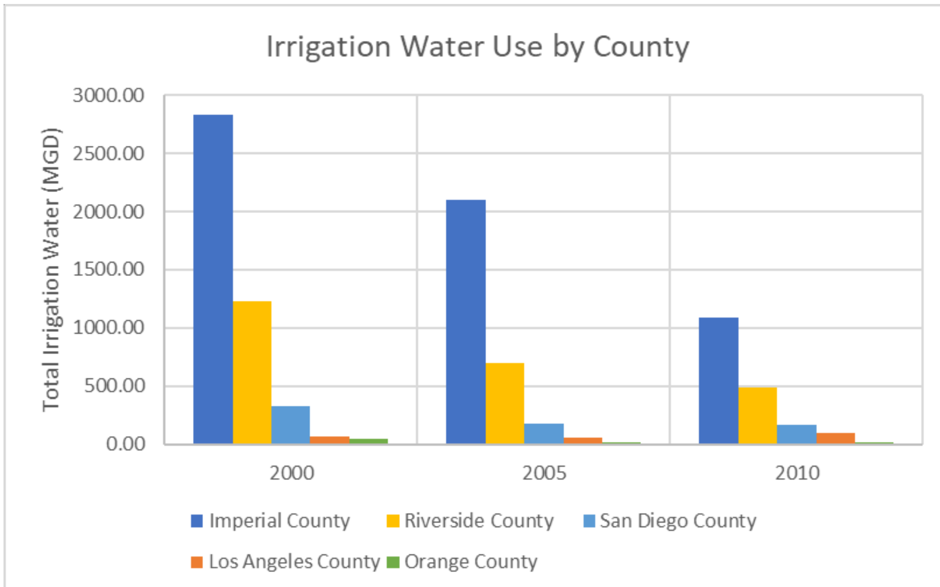



Figure 9. Water use by county, 2000-2010

An overall decrease can be observed in all five counties, particularly in Imperial and Riverside Counties, indicating that the measures set in place by the QSA have been impactful on agricultural water use. With a net decrease of over 1700 MGD in Imperial County between 2000 and 2010, the IID mitigation water is providing a substantial amount of water to the Salton Sea. Figure 10 shows the average irrigation water per acre for both Imperial and Riverside Counties.

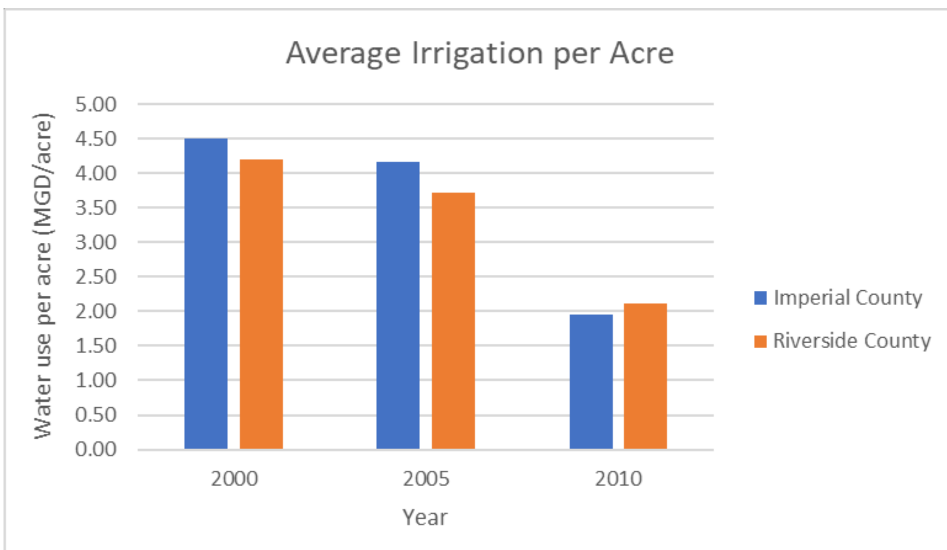



Figure 10. Average irrigation per acre, Riverside and Imperial Counties

The 2010 data indicates a clear decrease in irrigation water being used in both counties. This is indicative of the IID conservation efforts making a substantial impact, seven-years after the QSA implementation. As mentioned earlier, 2015 data would be useful in further relating the current inflows to the recent increase in mitigation water, but it can be assumed that this lack of water beyond 2017 will detrimentally impact the volume of the Salton Sea.

## 2.3 IMPERIAL AND RIVERSIDE COUNTY LAND COVER DATA

After studying the impacts the QSA has had on irrigation water use, land cover data was analyzed to see if the reduction in irrigation had caused a change in land cover type. It was hypothesized that there would be a shift from agriculture to developed land type, particularly in Riverside County, given the recent population increases.

### 2.3.1 Methodology

Land cover data for the State of California was acquired from the USGS Land Cover Institute for the years 2001 and 2011 [8]. Land cover raster data is provided in 30-meter cells in 16 distinct categories based on land type. For simplification purposes, the data was reclassified by utilizing the reclassify tool as indicated in Table 3 below.

Table 2. Reclassified land cover classes

| USGS Class Number | Reclassified Category |
|---|---|
| 0 | Unclassified |
| 21-24 | Developed |
| 41-43 | Forest |
| 71-82 | Agriculture |
| 31 and 52 | Shrub and Basin |

The reclassified rasters were extracted for Imperial and Riverside Counties. The rasters were reclassified further to assign a value of 1 to every cell with agricultural land cover and a value of 0 to every cell with all other types of land cover. The raster calculator tool was employed to subtract the reclassified 2011 land cover raster from the 2001 land cover raster to visualize changes in agricultural land cover between the ten-year span. A value of 0 in the raster indicates that no land cover change occurred, a value of -1 indicates that the land cover changed from agriculture to another land cover type, and a value of 1 indicates that the land cover changed from another type to agriculture.

### 2.3.2 Data Analysis

Figures 10 and 11 on the following page show the land cover for Riverside and Imperial Counties in 2001 and 2011 respectively.

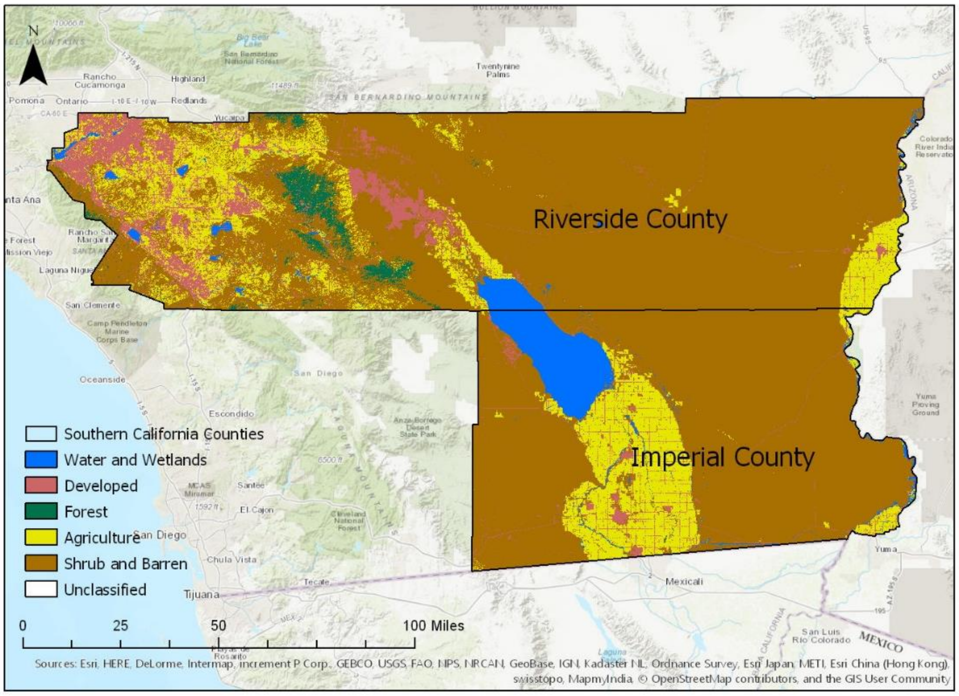



Figure 11. Land cover data for Riverside and Imperial Counties, 2001

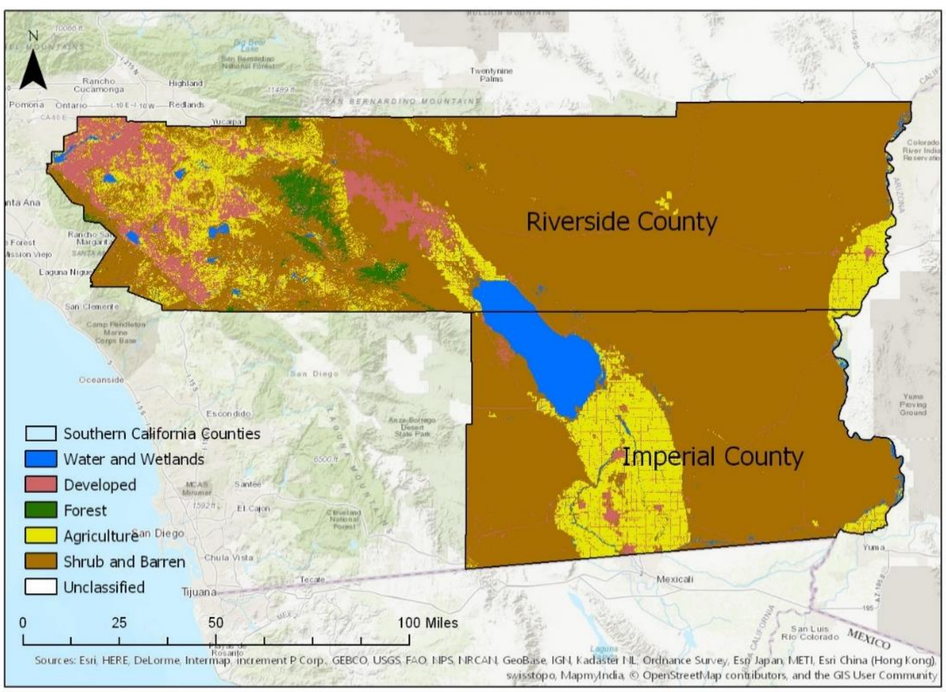



Figure 12. Land cover data for Riverside and Imperial Counties, 2001

Both counties are made up of a majority of shrub and barren land; large swatches of agriculture land are observed on the south and north ends of the Salton Sea (visible in blue). While it is difficult to see the subtle changes that occurred in such a large area over the ten-year period, Table 3 below summarizes the percentage of land type in the combined area in 2001 and 2011.

Table 3. Land cover percent of total area, 2001 and 2011

| Land Cover Type | Percent of Total Area (2001) | Percent of Total Area (2011) |
|---|---|---|
| Water and Wetlands | 3.93% | 3.84% |
| Developed | 6.61% | 7.31% |
| Forest | 1.38% | 1.37% |
| Agriculture | 13.92% | 13.48% |
| Shrub and Barren | 74.15% | 73.99% |
| Unclassified | 0.00% | 0.00% |

While major changes are difficult to see due to the overwhelming amount of shrub and barren land in these two counties, a small decrease in agricultural land and a correspondingly small increase in developed land can be noted when comparing the 2011 to 2001 land cover type. This correlates to the increase in municipal water usage seen in Riverside county along with the overall decrease in agricultural water use.

Raster analysis was performed to understand of wherethis land use change was occurring within the two counties. Figure 11 on the following page shows land use change occurring between 2001 and 2011.

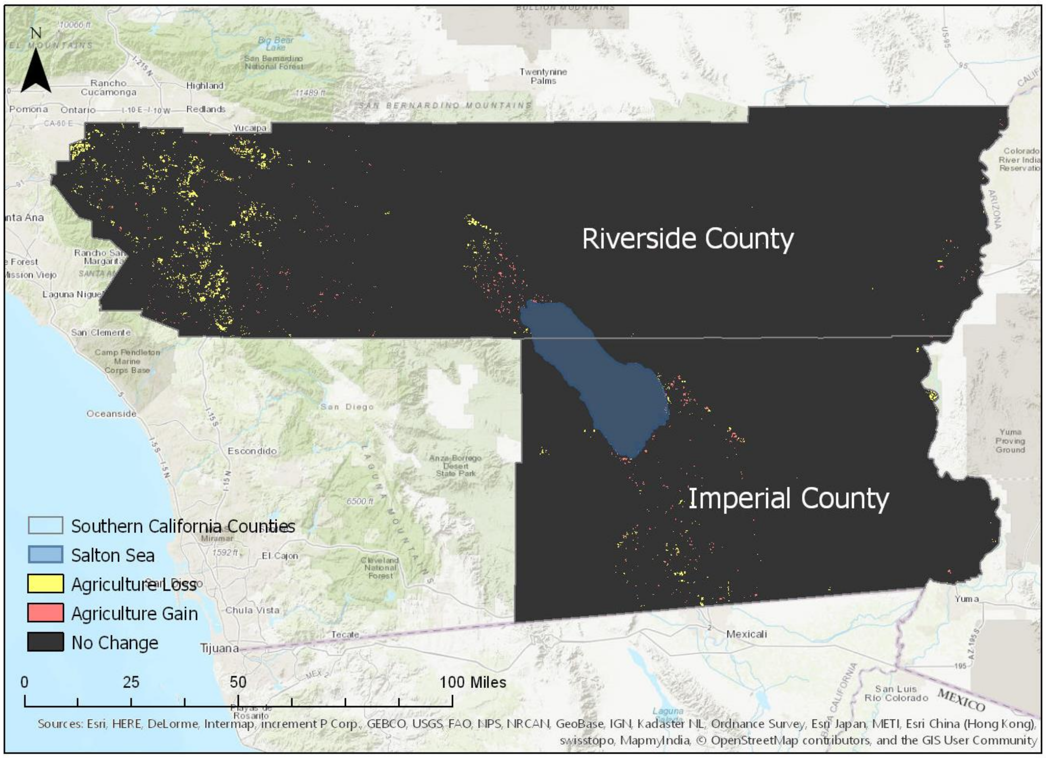



Figure 13. Agricultural land cover change in Riverside and Imperial Counties, 2001-2011

A majority of agricultural land losses occurred in the western part of Riverside County, likely due to new development activities and increasing population. These would not directly impact the inflows to the Salton Sea but would have an impact on the growing municipal water demands in the County. Within the vicinity of the Salton Sea, there appears to be relatively equal amounts of agricultural gains and losses. Total amounts of agricultural gains and losses are as follows:

- Total agricultural loss: 74.1 $mi^2$
- Total agricultural gain: 22.6 $mi^2$

Despite the lack of expected overwhelming agricultural land type loss near the Salton Sea, a net loss of 51.5 $mi^2$ is observed between the two counties. Lack of agricultural loss in Imperial County in particular can be explained by the general lack of developmental interest in the area compared with Riverside County as well as the current conservation techniques utilized by the IID. As previously noted, the IID is encouraging farmers to either fallow their land or adopt more conservative watering tactics. Additionally, agricultural land cover data is broken down into three categories by the USGS: hay/pasture, cultivated crops, and herbaceous. Agricultural land utilized for livestock pasture would require considerably less water compared to crops indicating that irrigation use could be decreasing without land cover type changing.

# 3 Conclusions and Limitations

The implementation of the Quantification Settlement Agreement in 2003 has changed the way water is used throughout Southern California. As population growth continues in San Diego, Orange, Riverside, and Los Angeles Counties, the growing demand for municipal water use must be offset by a continued reduction in irrigation water. While the overall decline in irrigation water use is beneficial from a conservation perspective, it will be detrimental to the Salton Sea water volume beyond 2017.

Land cover data shows that much of the agricultural land is remaining the same in Imperial County, the main contributor to Salton Sea inflows as indicated by the HUC8 watershed, but a reduction in irrigation per acre indicates effective use of conservative irrigation techniques put into place after the QSA. While inflows via the New and Alamo Rivers have remained relatively constant over the past 35 years, this is likely due to the mandated mitigation water provided by the IID.

As mentioned throughout this report, lack of cohesive data regarding the Salton Sea has left some gaps in drawing thorough conclusions. Once 2015 water usage data is available from USGS, a more complete picture of the current conditions will be drawn. Additionally, there was a surprising lack of publicly available data regarding the Salton Sea itself. It would have been helpful to have data showing recent water levels and/or surface area to understand how quickly the Sea will shrink in size following the end of IID mitigation waters.

Regardless, 2018 will bring drastic changes to the Salton Sea. When inflows are no longer making up for quick evaporative losses via the hot desert climate, the volume is anticipated to shrink quickly, exposing many of the inhabitants of the counties examined in this project to high concentrations of toxic dust and particles if not mitigated effectively by the State of California.

# 4 References

1. James, Ian, 2017. Toxic Dust and Asthma Plague Salton Sea Communities. USA Today https://www.usatoday.com/pages/interactives/salton-sea/toxic-dust-and-asthma-plague-salton-sea-communities/

2. QSA Annual Report, 2015. Imperial Irrigation District. http://www.iid.com/water/library/qsa-water-transfer/qsa-annual-reports

3. San Diego County Water Authority, 2003. Quantification Settlement Agreement. https://www.sdcwa.org/quantification-settlement-agreement

4. Simon, Matt, 2012. The Salton Sea: Death and Politics in the Great American Water Wars. Wired Magazine. http://www.wired.com/2012/09/salton-sea-saga/.

5. Than, Ker, 2014. Can California Farmers Save Water and the Dying Salton Sea? National Geographic https://news.nationalgeographic.com/news/2014/02/140218-salton-sea-imperial-valley-qsa-water-conservation/

6. American Fact Finder. US Census Data. https://factfinder.census.gov

7. Water-use Data, 2010. USGS. https://water.usgs.gov/watuse/data/

8. Land Cover Data, 2011. USGS. https://landcover.usgs.gov/