On the origin and evolution of the Salton Sea

David K. Lynch[1] and Brian McNeece
[1]*dave@caltech.edu*

ABSTRACT—It is widely written and generally believed that the Salton Sea was created by an engineering accident. Many called it a blunder, gross negligence by Charles Rockwood. But we argue that the catastrophic inundation of 1905 was a natural event. Triggered by the Gila River's largest flood on record, Colorado River water would have reached into the Salton Trough whether or not Rockwood's California Development Company (CDC) had been there at all. Indeed, historical records show that the Colorado River flowed into the trough as early as 1840, long before the CDC. After the 1905-1907 flood subsided, the Salton Sea might have been expected to evaporate and percolate away in a few years. And it would have if the Alamo Canal had not continued to bring in river water, more in fact than was needed. For the past 115 years, the sea has been maintained by river water, not as the primary goal, but as the only practical way to dispose of irrigation runoff. The original Salton Sea may have been formed catastrophically, but the modern sea's existence is intentional, an inevitable result of Imperial Valley agriculture. Today's Salton Sea has little or nothing to do with the 1905 flood and should not be called an accident.

1. Introduction

The dramatic formation of the Salton Sea in 1905 has been much discussed and extensively studied[1-7]. The usual story is this: poor water management of the Colorado River and Alamo Canal near Yuma diverted the river water into the Salton Trough, creating the Salton Sea. Many narratives assign blame to Charles Rockwood, who allowed water from the river to flow into the Alamo Canal through open cuts without constructing head gates to control the flow. When the Colorado flooded as a result of floods on the tributary Gila River, it coursed unchecked through Rockwood's Lower Mexican Heading and into the Imperial Valley. This is the basis for the prevalent notion that the sea was Rockwood's fault. Yet the story is more complicated, and an examination of historical records leaves room for other interpretations. We will not repeat the many fascinating accounts of the 1905 floods and subsequent return of the Colorado River to its natural bed in Mexico. Instead we will investigate two different though related topics: (1) The cause of the sea's 1905 inundation, and (2) some seldom-considered aspects of the sea's continued existence.

2. Origin of the Salton Sea

Water in the Salton Trough is nothing new. The geological record reveals that as a major body of water, Lake Cahuilla existed there episodically during the late Pleistocene and

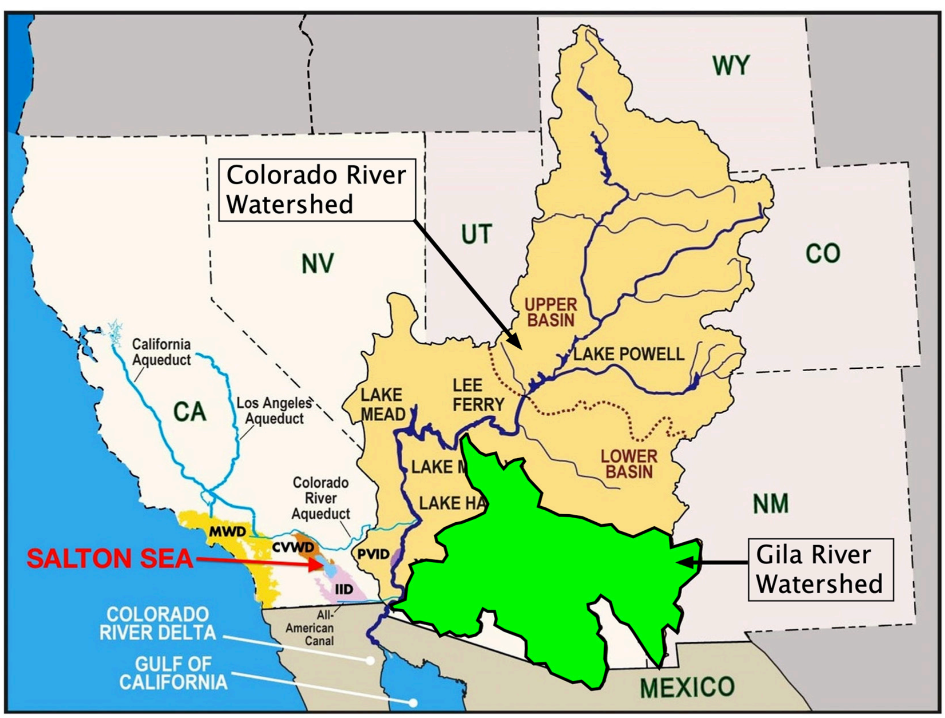

Figure 1. Drainage Basins of the Colorado and Gila rivers. Colorado River watershed includes the Gila's. Due to elevation, climate and latitude differences, the Gila River watershed is much warmer than the Colorado's. In winter, rain in the Gila's drainage basin runs off, but snow in the Colorado drainage basin stays on the ground. In summer, the Gila basin often experiences flash floods due to monsoons, less so in the upper Colorado basin because it is farther north and less likely to have monsoons. Figure adapted from the Central Basin Water District.

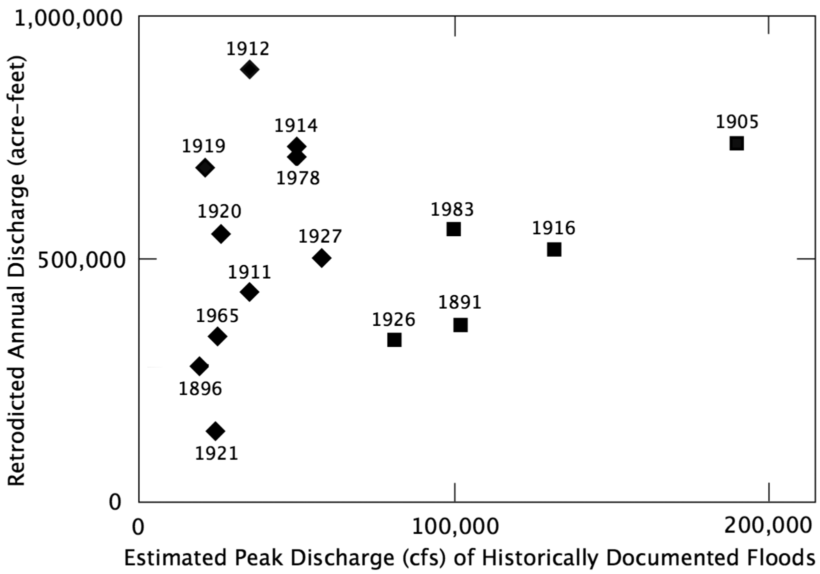

Figure 2. Historic Floods on the middle Gila River (adapted from Woodson, 2015)[18]. The earliest floods for which discharges and could be estimated ("retrodicted") were in 1891, 1896 and 1905. All three carried Colorado River Water into the Salton Trough. Given that the 1905 flood was much larger than the earlier ones, it seems certain that it produced a Lake Cahuilla, later called the Salton Sea. Squares are major floods.

Holocene at irregular intervals of between 500–1000 years[8]. Based on historical accounts[9], the last event was around 1540. Yet at least nine times in the 19th century (1840, 1842, 1852, 1859, 1867, 1862, 1884, 1891 and 1896)[10-13], there were reports of significant water in the trough, some with areas greater than the modern-day Salton Sea. In most cases, the water appeared after well-documented, natural floods on the Colorado River. The resulting short-lived lakes evaporated within a few years and had no enduring names, though some locals called them "inland seas". If we call natural occurrences "Lake Cahuilla" and manmade ones "Salton Sea", these 19th century bodies of water should have been called Lake Cahuilla. Thus, the lake's last highstand was 1896. If it can be established that the 1905 flood was a natural event, Lake Cahuilla's last highstand would be reckoned as February 1907.

As a manmade body of water, the Salton Sea formed in 1901, not 1905 as is usually cited[14-15]. In May 1901, water began flowing from the river along the newly constructed Alamo (Imperial) Canal and reached the Imperial Valley in June[1-7]. It seems that no one considered what to do with the water after it was used for irrigation, so it simply trickled down to the bottom of the sink. It was little more than a transitory wetland that didn't bother anyone. But it quietly marked a historic event for southern California's water saga: the birth of the Salton Sea.

The sea's catastrophic growth in 1905 is best understood by examining the source of the lower Colorado River's water before damming in the 20th century. Figure 1 shows its drainage basin, which includes that of the Gila River basin. Both watersheds reached their present configuration about 5 million years ago (early Pliocene). The Gila River's 58,000 sq mi drainage basin is mostly in Arizona, while the much larger Colorado drainage basin (246,000 sq mi, which includes the Gila's) extends as far north as Wyoming and as far east as Colorado and the Rocky Mountains. On average, the Gila watershed is at a lower elevation (2800 ft estimated) than the Colorado's (5500 ft), and is more southerly. Thus the Gila watershed is warmer than the Colorado's. Assuming a mean temperature drop off with elevation (adiabatic lapse rate[16]) of 18°F/mile, it is on average 9°F colder in the Colorado watershed than in the Gila's: When both climate and latitude are considered, another ~20°F is added. As an example, when it's 40°F and raining in Yuma, it's 11°F in Laramie and snowing.

The rivers have different seasonal variations. During winter, the Colorado River's discharge is low because precipitation in its upper drainage basin tends to be snow, which sticks to the ground and does not run off. Winter floods from the upper Colorado are rare but they occasionally occur on the lower, warmer Gila. Precipitation in the Gila watershed is mainly rain and it runs off to join the lower Colorado, but the discharge is normally small.

In the summer, weather patterns are different. Rain and snowmelt runoff from the Colorado swells the river from April to August and is fairly predictable. Monsoon[17] rains over the Gila watershed are unpredictable. They only occur in summer and affect relatively small areas, not the entire watershed. Monsoons can dump enormous amounts of water on the desert, enough to create flash floods.

Snowmelt and monsoons would seem to make summer the season for floods. But in 1905, the floods came in winter. And not from the Colorado River *per se*, but rather from its tributary, the Gila River[1-7]. What sparse data exists on Gila River floods is sufficient to gain some insight into its influence on the Colorado River.

Historic floods on the Gila[18] have been characterized by their *total discharge* and *peak discharge* (Figure 2). Prior to modern instrumentation, these values could only be estimated, but Figure 2 reveals that the 1891 and 1896 Gila floods, both being natural events, sent river water into the trough. Since the 1905 flood was much larger than the previous two, it seems certain this flood would have also overwhelmed the Colorado and created a Lake Cahuilla.

To see the actual timing, consider Figure 3, which shows the daily discharge of the Colorado and Gila Rivers in 1905, along with the typical daily discharge of

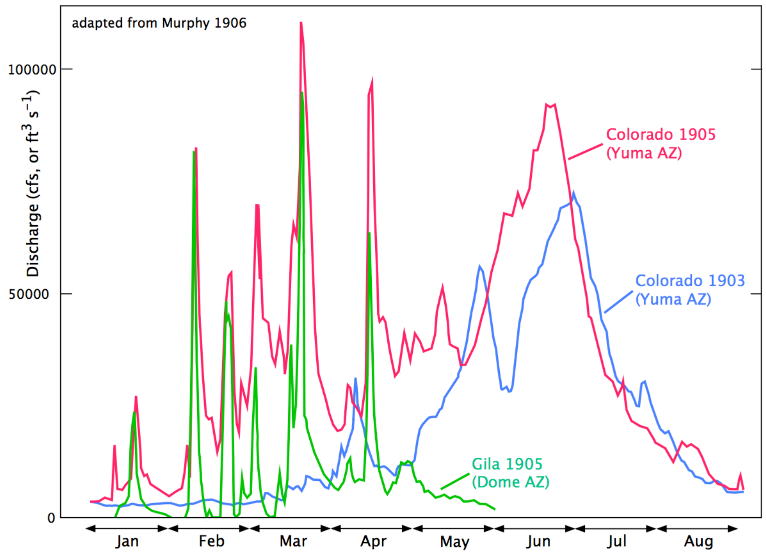

Figure 3. Colorado River discharges at Yuma, AZ and Gila River discharges at Dome, AZ. In normal years (1903), the Colorado River discharge peaks in summer. The Gila is usually very low or dry. In 1905, however, the Gila flooded at least 5 times, pushing the Colorado to record levels. Each flood on the Colorado was preceded (by a few hours) by floods on the Gila. Figure adapted from Murphy (1906).

the Colorado in 1903[19]. Normally the Colorado and Gila were low in the winter and early spring. While the Gila remained low all year, the Colorado discharge increased ~ten-fold from snowmelt in spring and summer. Since the Gila flows into the Colorado above Yuma, pulses of water on the Gila eventually reach the Colorado. Indeed, Figure 3 shows that in 1905, each flood on the Gila reached the Colorado a few hours later. Considering the total discharge in 1905—the area under the 1905 Colorado curve—it seems that the unusual but still natural floods on the Colorado were by themselves sufficient to inundate the trough.

If the 1905 floods were natural events, why hasn't the Colorado flowed into the trough again? After all, in 1909, the discharge was enormous[20], larger than any during 1905–1907, yet no water found its way to the trough. The answer is that Rockwood and Cory had learned their lesson and greatly enlarged the levees surrounding the Alamo Canal[21].

To summarize, the 1905–1907 Colorado River flood waters came through Rockwood's open cut in Mexico. This was the basis for believing the Salton Sea was the result of an engineering accident. But water reached the trough through the cut simply because it was the most efficient route at the time. Had this opening not been present, the 1905 Gila flood would have overflowed the Colorado, breached a levee somewhere else and made its way to the Salton Trough.

3. The enduring Salton Sea

What happened to the Salton Sea (not yet named) in 1905 is a matter of historical record[1-7]. By June a shallow body of water covering 150 sq mile (~12 x 12 miles) had collected at the bottom of the trough as 80,000 CFS flowed in. By October, the entire river reached the trough. The Salton Sea grew rapidly as the entire Colorado River flowed into the Salton Trough. Surging across the desert, the flood overran huge portions of the Mexicali Valley in a sheet of braided channels 8–10 miles wide (Figure 4). It reached Volcano Lake at the foot of Cerro Prieto and was channeled north to the New River, turning a shallow brush-filled depression into a torrent. Ultimately, Harry Thomas Cory, who made many courageous decisions concerning the flood and who probably convinced E. H. Harriman to fund the effort, took over. He closed the cut and finally put the Colorado River back where it belonged on February 10, 1907.

Once the Colorado River was returned to its former bed, the disaster was over but the Salton Sea remained. Left to itself, it would have vanished by about 1917 (Figure 5), losing about 6 ft per year to evaporation and percolation[22]. But with agriculture once again flourishing, the CDC kept the water flowing. After irrigating the fields, water was left to drain into the sink. While the flooding of 1905-1907 was a surprise, today's Salton Sea is not. It is there because farmers want it there. Not because they particularly like it, but because the sink was the natural sump for

Figure 4. Published reports refer to a broad 8–10 mile wide shallow flood in 1905 as a sheet-like flow or shallow braided channels. No maps of the flood flow were produced because there were no surveyors in the areas during 1905-1907. This image is consistent with historic reports. Adapted from the Salton Sea Atlas, Redlands Institute (2002).

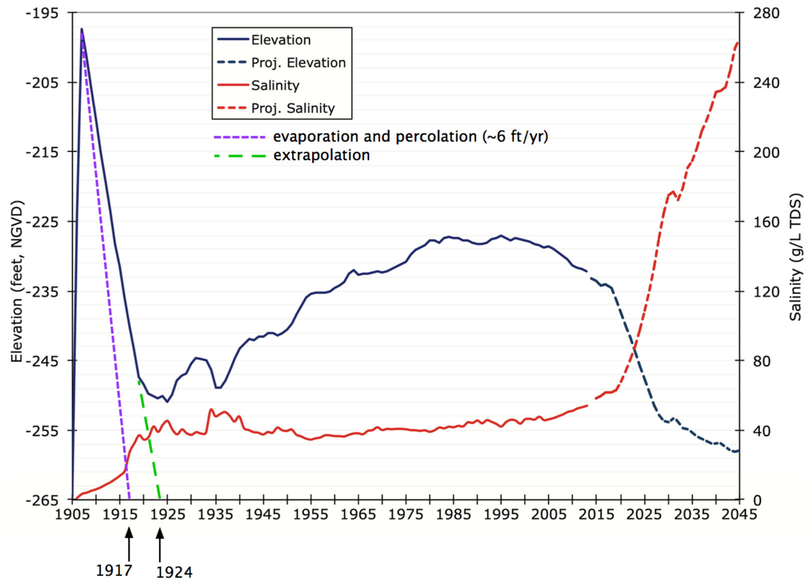

Figure 5. After the flood was stopped, the Sea level dropped sharply. This was due mostly to evaporation and percolation. Had the CDC not allowed Colorado River water to enter the trough through the Alamo Canal, the Salton Sea would have disappeared by about 1917. But the continuing growth in agriculture required more water than ever and the Sea level rose from 1925 until 1983.

their irrigation water. Indeed, President Coolidge formalized this in 1924 by an executive order setting aside land under the sea as a permanent drainage reservoir[23].

As Figure 5 shows, the Salton Sea grew steadily between 1924 and 1983. Part of its enlargement occurred because more and more water was needed to supply the growing acreage of farmland. But there was another reason. Farmers were taking more water than they needed to grow crops because they were trying to desalinate the soil and thereby improve crop yields. As an endorheic basin, sediments in the trough have accumulated salt and other evaporites from thousands of years of evaporation. Most evaporites are on or near the surface because the clay-like soil is poorly drained. To remove it, farmers began using an ancient desalination technique known to the Indus Valley Civilization[24], and this requires a lot of extra water; *deep drainage.*[25-27]. In 1920s, the Imperial Irrigation District (IID) began a massive program to desalinate the soil.

In deep drainage (Figure 6), long lines (miles) of perforated or porous pipes are placed at a slight inclination a meter or so below ground, then covered. Though the soil is poorly drained, water eventually makes its way down to the pipes and is carried down to the sea by gravity, primarily through the Alamo and New rivers. This water carries salt and agricultural fertilizer from the topsoil and soil in the vadose zone to the drain pipes. For deep drainage to be efficient, however, farmers had to use more water than they had taken earlier. For every three acre-feet of water that a farmer applied to the ground, one acre-foot ended up in the Salton Sea[28]. This practice of using extra water caused the Salton Sea level to rise even faster.

Deep drainage in the Imperial Valley does three things: it lowers a high water table, removes surface salt, and also dumps salt into the Salton Sea. This is why the Sea is so salty, almost twice that of the ocean in 2019[29]. Drain water also contains large amounts of fertilizer including nitrogen and selenium[30] (selenium is also found

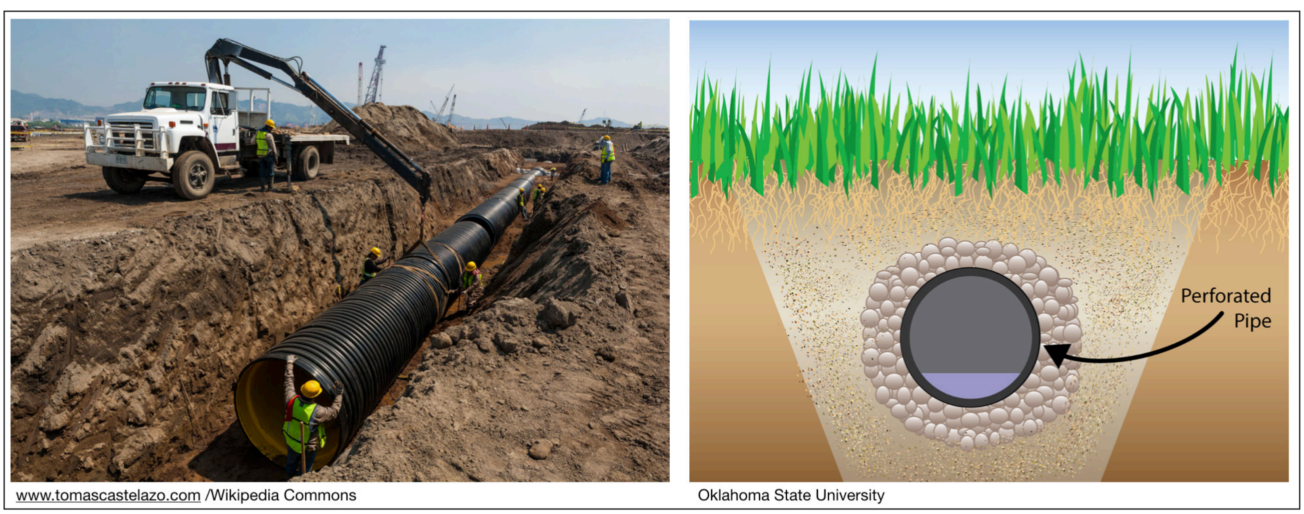

Figure 6. Deep drainage is a way to desalinate surface soils so that crops grow better. Perforated pipe inclined slightly downward toward the Sea are buried. Salt-laden water percolating down from the surface removes salt from the topsoil. This water and salt (and fertilizer), however, increase the salinity of the sea and raises its level. Deep drainage desalination requires more water than crops need.

in Colorado River water and sediments). Pollution from the Alamo and New rivers, the latter once called the most polluted river in the world, additionally adds to the sea's chemical soup.

Until the urban areas of Phoenix, Tucson, Los Angeles, and San Diego grew beyond water supplies, farmers in the Imperial Valley had no reason to limit their use of water. The IID receives its water from the Bureau of Reclamation for free; farmers are merely charged the cost to deliver the water. And since water is delivered by gravity, delivery is cheap. As a result, Imperial Valley farmers have paid some of the lowest rates in the nation. Today, they pay $20 for an acre-foot of water. In contrast San Diego area farmers pay above $900 for an acre-foot.[31]

Deep drainage, along with surface drainage known as *tailwater*, turned out to be a doubled-edged sword. Crops grew better, but in the late 1970s, agricultural drainage into the sea caused its level to rise enough to flood some productive agricultural land. The flooded farmers sued the IID. After years of litigation, the court ruled that the IID was wasting water and was ordered to begin conserving water in order to lower the elevation of the Salton Sea[32]. In 1984, Decision 1600 of the California State Water Resources Control Board forced the IID to limit water delivery to the Salton Sea and to accept funding from the Metropolitan Water District (MWD) of Los Angeles. MWD would pay for system improvements so the IID would use less water. In return, the MWD would receive 104,000 acre-feet of water annually. This was the first large agriculture-to-urban water transfer[33]. As of January of 2020, the IID now transfers nearly 500,000 acre-feet to Los Angeles, San Diego, Coachella, and Native American water districts. Because of these transfers, the Salton Sea, after decades of rising, is now falling.

Water will continue to flow into the Imperial Valley and maintain the Salton Sea for the foreseeable future because farmers need water. There are plans to shrink the sea but not to dry it up[34]. Eliminating the sea would mean eliminating Imperial Valley agriculture.

Summary and conclusions

The Salton Sea's origin and evolution have been a source of ridicule, uncertainty, misinformation, and speculation. While most people believe the initial formation took place in 1905 as the result of an engineering accident, it actually started in 1901 as man-made runoff from irrigation water brought from the Colorado River by the Alamo Canal. *We argue that the Salton Sea's 1905 "formation" was simply another natural inundation from a Colorado River flood, triggered by floods on the Gila.* The sea's beginning was inevitable, if not intentional. Nor is the sea's continued existence an accident. Rather it is a deliberate, even desirable, result of agriculture in the Imperial Valley and its farmers' efforts to desalinate the soil.

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