

Battling Seawater Intrusion in the Central & West Coast Basins

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Seawater intrusion is the movement of ocean water into fresh groundwater, causing contamination of the groundwater by salt. It is a natural process that can be made worse by human activities. Virtually all coastal aquifers around the world experience seawater intrusion to some degree due to the density differences between salt water and fresh water. If two equally tall columns are filled with water, one with seawater and the other with fresh water, the pressure at the bottom of the seawater column will be greater than at the bottom of the fresh water column. This is because the seawater has a higher mineral content than the fresh water (more salt), making it denser than the fresh water. If the two columns are connected at their bases, the seawater will flow into the fresh water column because of the pressure differences. The fresh water column will have to be filled higher than the seawater column to balance the pressures and the flows.

The same thing happens in nature along the coast where groundwater levels (a.k.a. heads, elevations, or potentiometric surfaces in a confined aquifer) approach sea level. The two “water columns” are equal in height and there is a natural flow of seawater inland into the fresh groundwater (**Figure 1a**). This intrusion is halted naturally when the groundwater levels rise and overcome the pressure of the seawater (like the taller column of fresh water). The relationship between the fresh water and seawater pressures is described by the Ghyben-Herzberg principle, which is based on the density differences between the two fluids. It gives an approximation to the depth to the seawater/fresh water interface and states that for every foot above sea level the fresh water head is, the depth to the seawater will be 40 times this amount below sea level. For example, if the potentiometric surface is 5 feet above sea level, the depth to the seawater will be approximately 200 feet below sea level. If groundwater levels drop a foot, then the interface will rise 40 feet.

In coastal areas where groundwater is used for potable or agricultural purposes such as the Central and West Coast Basins (CWCB), intrusion can be a serious problem resulting in the shut down of wells or necessitating expensive desalination treatment. In the early half of the 20th century, groundwater extractions in the CWCB were double natural replenishment, causing severe overdraft and lowering of the groundwater elevations to over 100 feet below sea level. This greatly increased the extent of the

seawater intrusion inland (**Figure 1b**). Callison and Roth (1967) reported that seawater intrusion was first noted in Redondo Beach in 1912, Hermosa Beach in 1915, and El Segundo in 1921. The California Department of Water Resources (CDWR, 1962) estimated that up to 600,000 acre-feet (af) of seawater intruded into and contaminated the Los Angeles coastal aquifers by the late 1950s.

To address this problem, in 1951 the Los Angeles County Flood Control District (LACFCD) used an abandoned water well in Manhattan Beach to inject potable water to test whether pressure could be built up in a confined aquifer to block the intrusion (Lipshie and Larson, 1995). The test worked, so LACFCD performed subsequent tests with additional wells to successfully create a pressure ridge or “wall” along the line of injection wells to overcome the pressure of the intruding seawater (**Figure 1c**). The results are well documented in a report by CDWR (1957).

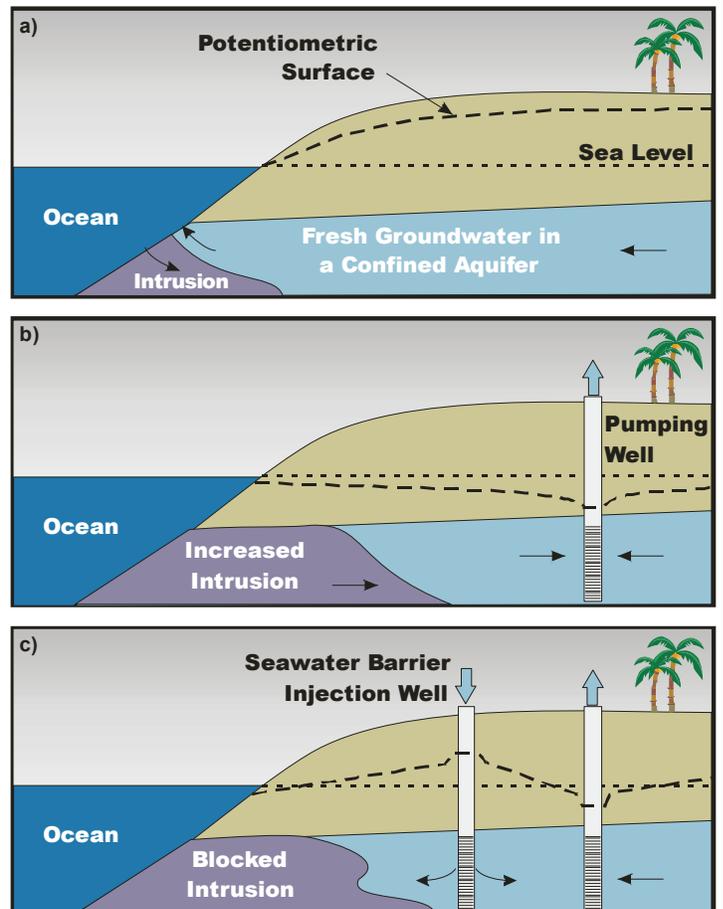


Figure 1 - Seawater Intrusion and Barrier Wells:
a) Natural condition where the potentiometric surface slopes towards the ocean and there is minimal intrusion;
b) Excessive pumping draws the potentiometric surface below sea level causing increased seawater intrusion; and
c) Injection well builds up pressure so that the potentiometric surface rises above sea level and blocks the intrusion.

Based on the success of the tests, the LACFCD eventually constructed the West Coast Basin Barrier Project, the Dominguez Gap Barrier Project, and the Alamitos Gap Barrier Project. The locations of these projects are shown on **Figure 2**. The barrier wells inject water into the aquifers to build up a line of pressure equal to or exceeding the protective elevations predicted by the Ghyben-Herzberg principal, blocking the intrusion.



Figure 2 - Location of Seawater Barrier Projects

The barrier projects have been successfully protecting the fresh water aquifers in the CWCB for over 50 years. Currently, both potable water and recycled municipal wastewater treated by microfiltration, reverse osmosis, and advanced oxidation in some cases (ultraviolet light and hydrogen peroxide) are used. The water is injected into the CWCB aquifers to depths up to 700 feet. **Table 1** presents some construction details for the barrier projects. The LACFCD owns, operates, and maintains the barrier projects. WRD purchases all of the water injected into the barriers, except for about 2,500 af per year purchased by

Barrier Project	West Coast	Dominguez Gap	Alamitos Gap
Date Started	1953	1969	1964
Overall Length (miles)	9	6	2.2
Number of Injection Wells	153	94	43
Number of Observation Wells	302	232	239
2008 Injection Amounts (estimated acre feet)	13,600	11,000	6,000

Table 1 - Barrier Details

the Orange County Water District for a portion of the Alamitos Barrier. The recycled water for the Alamitos Barrier is treated by WRD, for the West Coast Barrier by the West Basin Municipal Water District (WBMWD), and for the Dominguez Gap Barrier by the City of Los Angeles. Potable water is provided by WBMWD and the City of Long Beach. The cost for the injection water in 2007/2008 is approximately \$14 million, and the maintenance costs may approach \$4 to \$5 million.

Due to the aging infrastructure, rising water and maintenance costs, and uncertainty of long-term potable water availability, all six agencies participate in cooperative efforts to optimize barrier performance, minimize costs, and to ensure continued barrier effectiveness. Alternatives to injection wells for seawater intrusion control were reported in Johnson and Whitaker (2004). In addition, if regional groundwater levels were to rise due to reduced pumping, then barrier efforts and associated costs would be reduced. Attempts are being made to replace the groundwater pumped from wells along the coast that is used only for industrial purposes with recycled water. If successful, the reduced pumping will increase groundwater levels along the coast and reduce the amount of injection water needed to maintain a protective barrier.

In conclusion, injection wells have been successfully used to battle seawater intrusion in the over-drafted CWCB aquifers since the early 1950s. The precious groundwater resource has been mostly spared from additional salt contamination because of the barriers. However, the rising cost of the barrier system and the aging infrastructure requires alternatives to be developed. The future will likely see innovative ways to protect the aquifers from seawater intrusion while minimizing costs to the overlying groundwater users.

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