DEPARTMENT OF THE INTERIOR
UNITED STATES GEOLOGICAL SURVEY

PREPARED IN COOPERATION WITH THE
HAWAII STATE DEPARTMENT OF LAND AND NATURAL RESOURCES
DIVISION OF WATER AND LAND DEVELOPMENT

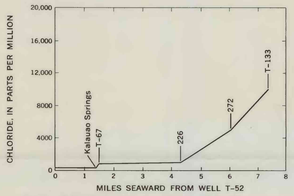
HYDROLOGIC INVESTIGATIONS
ATLAS HA-267 (SHEET 2 OF 2)

CHLORIDE CONCENTRATION OF THE WATER

The chloride concentration of water has been used for many years in Hawaii as an index of suitability and as an indicator of sea-water intrusion. The concentration is expressed as parts by weight of chloride to one million parts of water (ppm). The maximum concentration recommended for drinking water is 250 ppm, water used for irrigation on Oahu contains more than 800 ppm (well 197), and the sea water in the basaltic aquifer contains more than 15,000 ppm.

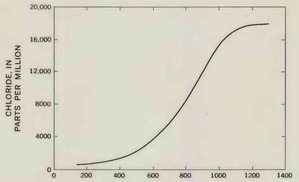
The chloride concentration varies with geographic location, depth, and time, and thus it is difficult to isolate the effects caused by changes in land or water use.

The variance with geographic location is demonstrated by the isochlors for the top part of the basal water, 1965, which were constructed with data from shafts and shallow wells (penetration of less than 50 feet below the water table). Fresh rainwater that infiltrates in the Ewa Forest Reserve contains less than 20 ppm. As the ground water flows toward points of discharge the top part of the basal water becomes more concentrated with chloride, exceeding 500 ppm near Barbers Point. The increase is caused in part by the infiltration of return irrigation water of higher chloride concentration and in part by mixing with water in the transition zone (geochemical section). Seaward from the points of discharge the chloride concentration abruptly increases to about 1,000 ppm. Between the 1,000- and 2,000-ppm isochlors the concentration varies with time (graph 268 and 201). Seaward of the 2,000-ppm isochlor the concentration again increases abruptly, reaching 10,000 ppm at well T-133.



Relation of chloride concentration of the top of the basal water to distance along geochemical section A-A' from T-52 (projected).

The relation of chloride concentration to depth is demonstrated by results from well T-67, which was sampled at various depths during drilling. This change in concentration with depth is similar to changes determined in tests at three other deep test wells drilled on Oahu and is probably representative of conditions in much of the Pearl Harbor area. Wells 197 and 239A-N were drilled to 899 and 664 feet below sea level, respectively. The concentration of chloride in the water from these wells is presently in excess of 800 ppm, whereas the concentration at the top part of the basal water is about 100 ppm. The remainder of the wells pump water from a shallower depth, and the shafts are dug to about sea-level elevation.

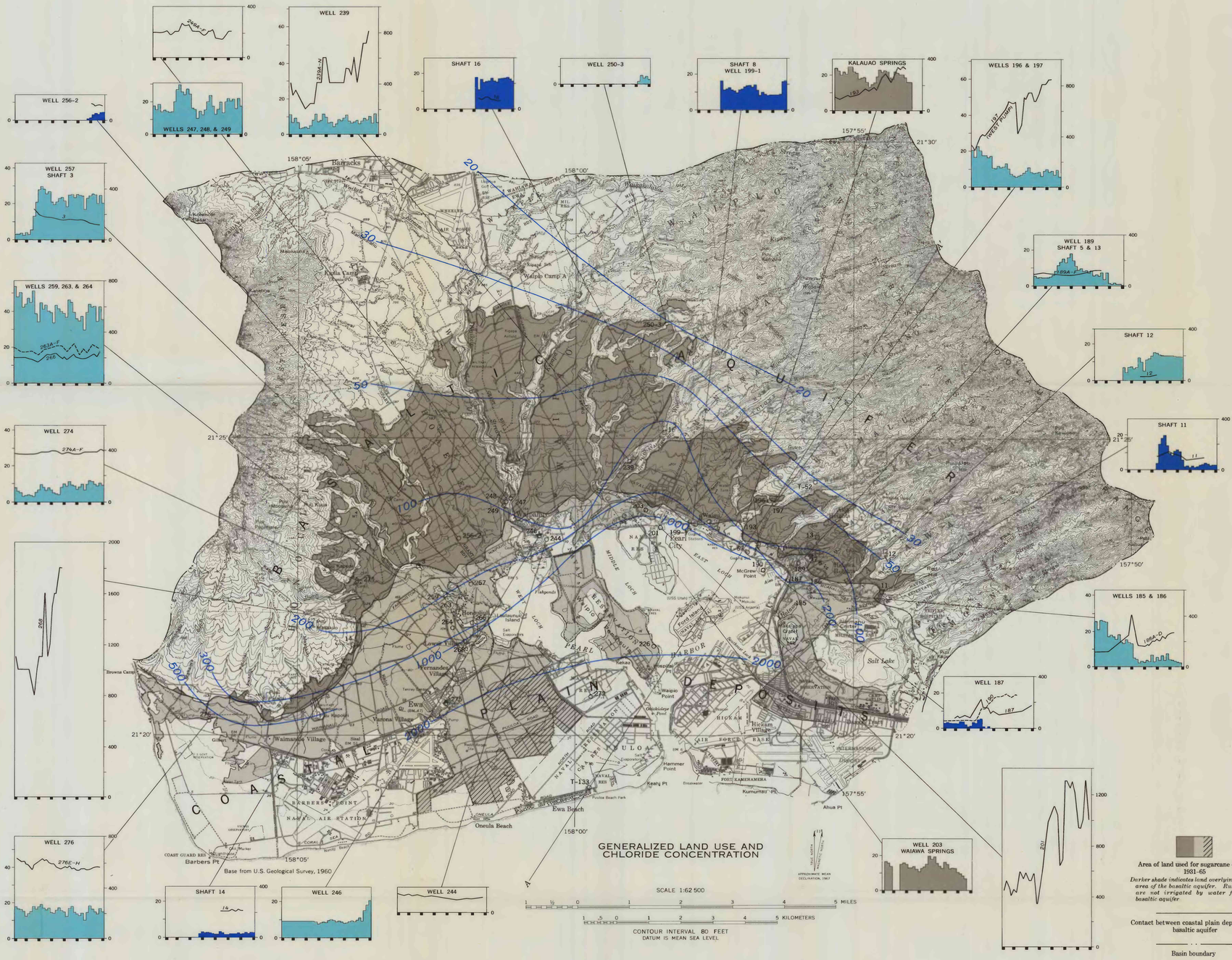


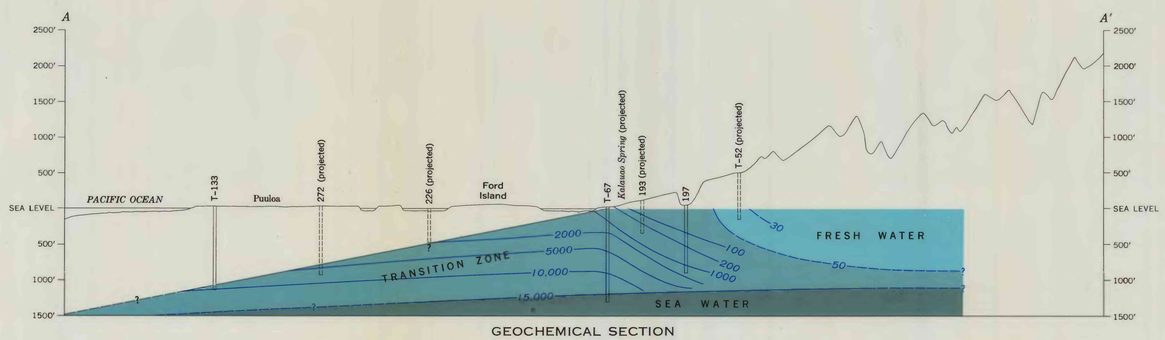
Relation of chloride concentration to depth in Well T-67.

There are three types of chloride concentration changes related to time. One is the extremely large seasonal fluctuations in concentration in wells between the 1,000- and 2,000-ppm isochlors, which are seaward of the points of discharge (201 and 268). The second type is the overall increase in concentration for the deeper wells (197 and 239A-N). And, the third type is related to a change in pumping rate. The first type is beyond the scope of this report. The second and third types are discussed in the following paragraphs.

Four wells (197, 201, 239A-N, and 268) have shown large increases in chloride concentration. Well 197 has shown an increasing trend throughout the entire period, while wells 201, 239A-N, and 268 had abrupt increases starting in 1944, 1940, and 1938, respectively. The pumpage increase (sheet 1) of 35 mgd between 1937 and 1940 may have caused the increase in chloride in wells 201, 239A-N, and 268. But the increasing trend in chloride concentration in well 197 that has existed throughout the period indicates that a landward or upward movement of high chloride water existed prior to the change in pumping rate at that place.

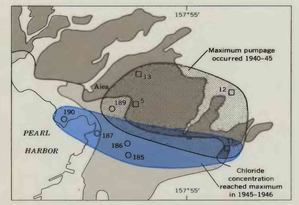
During the period 1940 through 1945 there was an increase of 31 mgd of water pumped mostly from shafts in the Aiea area (189, S5, S13, S11, and S12). The chloride concentration of water from installations seaward of the new development (S11, 186A-D, 187, and 190) began to rise sharply, increasing as much as threefold in well 186A-D. In 1946 through 1948 the pumpage in the area was reduced by 26 mgd. There was a decrease in the chloride concentration of the water, but not to the level preceding the large development. Apparently, this heavy pumpage exceeded the fresh ground-water flow, thus causing an encroachment of saline water that has not wholly been displaced by fresh water since. The fact that the chloride concentration increased in seaward wells in this case favors inland movement of the transition zone rather than an upward movement.





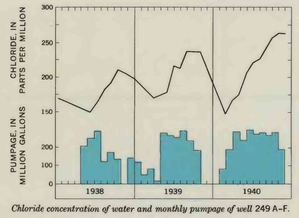
GEOCHEMICAL SECTION

Fresh water, less than 50 ppm chloride, grades both laterally and vertically into sea water. 1965 conditions. The three components, fresh water, transition zone, and sea water, form the basal water system. Isochlors and geologic contacts dashed where uncertain, queried where unknown.



Salt-water intrusion near Aiea, 1945–46.

In 1939, the pumpage was increased by 8 mgd in wells 247, 248, and 249. In previous years the chloride concentration of the water was about 150 ppm during the nonpumping season, and chloride concentration would approach 200 ppm during the pumping season. In the period 1940–46 when the pumping was almost continuous, the chloride concentration of the water increased and stabilized at about 250 ppm. In 1946 when pumpage was decreased 8 mgd to the prior rate, the chloride concentration of the water followed the pre-1939 trend. Because the effect of the increase in pumpage was not detected in seaward wells, and because there was no residual increase in chloride, it is reasonable to assume that this case represented a reversible upward movement of the transition zone rather than movement inland.



Chloride concentration of water and monthly pumpage of well 249 A–F.

CONCLUSIONS

Throughout the period of study the ground-water discharge rate has been about 250 mgd. Agricultural pumpage has been decreasing while urban and industrial pumpage has been increasing. There has been a decrease of 10 mgd of infiltrated irrigation water causing a net increase in ground-water discharge. The 10 mgd net increase is less than 5 percent of the total ground-water flow and consequently the effects cannot be measured.

The changes in chloride concentration are clearly related to at least the three different variables: geographic location, depth, and time. Because of these variations it is difficult to determine the changes in chloride concentration caused by changes in land use.

Large changes in pumping rate caused related changes in chloride concentration of the water, but in some cases there was no clearly related change. In the cases cited, heavy pumping by shafts caused an inland movement of saline water, and heavy pumping by wells caused an upward movement of saline water.

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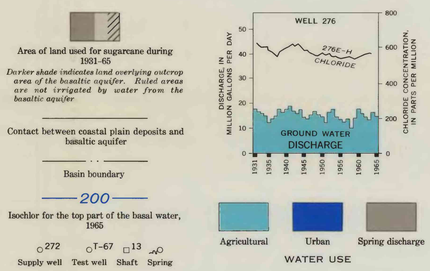
EXPLANATION



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LAND USE AND ITS EFFECT ON THE BASAL WATER SUPPLY, PEARL HARBOR AREA, OAHU, HAWAII, 1931–65

By
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1967