

C-14

ATTACHMENT

REVISED

**ELEVATION CHANGES
IN THE
CITY OF LONG BEACH**

NOVEMBER 2014 THROUGH APRIL 2015

PREPARED

FOR

LONG BEACH CITY COUNCIL

BY THE

**LONG BEACH GAS AND OIL
DEPARTMENT**

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ELEVATION SURVEY ANALYSIS

The City of Long Beach semi-annual elevation survey of the Civic Center, Central City, Harbor District, Alamitos Bay, Naples, and offshore drilling islands was conducted during May 2015. Changes in elevation that have occurred since the last two surveys, November 2014 and May 2014, are discussed in this report. The results in this report reflect elevation changes both within and beyond the scope of oil field operations. Some changes are due to natural geologic factors.

Elevation Change – November 2014 through April 2015

(Figure 1)

Elevations throughout the Alamitos Bay, Naples, Central City and the Civic Center were stable during the six-month period. The offshore drilling islands were stable except for a small area adjacent to Island Grissom which experienced a decline of 0.06 foot (0.7 inch). The decline is on the high end of normal limits, but still considered minor and will be closely monitored.

The Harbor District was stable during the six-month period. Elevation losses across the area observed in the November 2014 survey did not continue. The completion of drilling operations and an effective mitigation plan contributed to the stability of the area.

Elevations in the City of Long Beach to the north of the boundaries of the Wilmington Oil Field indicate the region was slightly up during the six-month period.

Elevation Change – May 2014 through April 2015

(Figure 2)

Elevations in the Alamitos Bay and Naples areas were stable during the twelve-month period. The Civic Center and Central City were stable with the exception of two relatively small areas noted in the most recent survey, where losses of up to 0.06 (0.7 inch) and 0.08 foot (1.0 inch) were measured. The losses are still considered minor at this time, and adjustments to field development activities have been made to mitigate further changes.

The offshore drilling islands were stable during the period, with the exception of Island White, which experienced a decline of up to 0.07 foot (0.8 inch). The elevation fluctuation is likely due to development activities in the area and, although noteworthy, is still considered within normal limits.

The Harbor District was deemed stable in most areas during the twelve-month period. Notable exceptions were Piers A and S, where net declines up to 0.16 foot (1.9 inches) were measured. The mitigation plan put in place by the City subsequent to the November 2014 survey appears to have been effective in stabilizing most of West Wilmington. The issue areas will be subject to further mitigation action if no improvement is seen at the next survey event in November 2015.

Use of Global Positioning System (GPS)

This report is based solely upon computer processed data utilizing the Long Beach Deformation Network (LBDN). The LBDN consists of thirteen permanent, reference GPS base stations, communication equipment, computer server, monitoring software and five mobile GPS receivers. The Public Works Department's Bureau of Engineering surveyors utilize the mobile GPS receivers linked to the reference base stations to measure approximately 240 City and Harbor bench marks.

APPENDIX

Brief History of Long Beach Subsidence

Long Beach and the general vicinity have a history of regional subsidence (losses of elevation) since 1929. Elevation changes were minor, amounting to an average of about -0.036 foot (-0.43 inch) per year until about 1939. Geologic movement such as the Long Beach Earthquake of March 1933 altered this average rate at times. Contributing causes of the subsidence were groundwater withdrawal from aquifers in the Long Beach area, regional basin sediment compaction, and tectonic effects of local faulting.

Development of the Wilmington Oil Field began in 1932. Oil operations accelerated subsidence and created a 29-foot deep subsidence bowl centered in the Wilmington-Long Beach Harbor area near Bench Mark 8772, at the Edison power plant. Development of the Ranger Zone west of Pine Avenue and its extension seaward in 1947 started the first definitive subsidence in the Central Business District that could be attributed to oil production.

Repressuring operations began in the 1950s. By 1965, subsidence stopped throughout the Long Beach portion of the Wilmington Oil Field. Several bench marks recovered over one foot in elevation, due to waterflood repressuring. As an example, from 1960 to 1970, Bench Mark 1735, near the corner of Ocean Boulevard and Magnolia Avenue, recovered approximately one foot of elevation. The recovery of bench mark elevations is known as rebound.

The Alamitos Bay and Naples area had losses in elevation prior to development of the adjacent oil operations. These original small losses were most likely due to the regional

effects of basin sediment compaction and tectonic movements along the Newport-Inglewood Fault Zone. Later, the coastal strip from the Civic Center eastward to the Alamitos Bay Peninsula lost elevation due to oil and gas production from the West Wilmington Oil Field and possibly the adjacent oil fields. The coastal strip rebounded slightly due to water injection from the offshore Oil Islands that began in 1965.

Survey Accuracy

The May 2002 Elevation Leveling Campaign marked the conversion from spirit, first and second order rod leveling, to GPS surveying of bench mark elevations.

Through statistical analysis of satellite, base station, and mobile instrument geometries, a coincident spirit leveling and GPS bench mark elevation survey, City surveyors estimate the relative accuracy of GPS elevations to be 8 to 10 millimeters (0.025 foot or 0.30 inch). Areas are considered to be stable where elevation change is less than 0.050 foot (0.60 inch) over a six-month survey period.

Studies by the City's subsidence control engineers, geologists, and consultants show that the bench marks may, at times, rise and fall somewhat concurrently city-wide in such a manner as to make an entire survey either optimistic or pessimistic. These elevation changes are random and not well understood. Repressuring operations and the resulting rebound can mask the rise or fall pattern. Surface elevations in a rebounded area can be expected to fluctuate under changing water flood conditions. Because of these fluctuations, conclusions based upon short-term survey data should be viewed with caution. Short-term survey data are useful for possible early detection and confirmation of subsidence trends or relative elevation changes, but should not be accepted without consideration of the above factors. Annual survey data tend to average these fluctuations and depict a more dependable picture of the relative movements of bench marks.

Elevation Change Map Construction

(Figures 1 and 2)

All data are presented as contour lines showing the average change in surface elevation during a particular time period. For example, any point along a line reading 0.05 foot (0.60 inch) on an Elevation Change Map gained an elevation of one-twentieth of a foot or six-tenth of an inch during that period. The small hachures along contour lines point towards a loss in elevation.

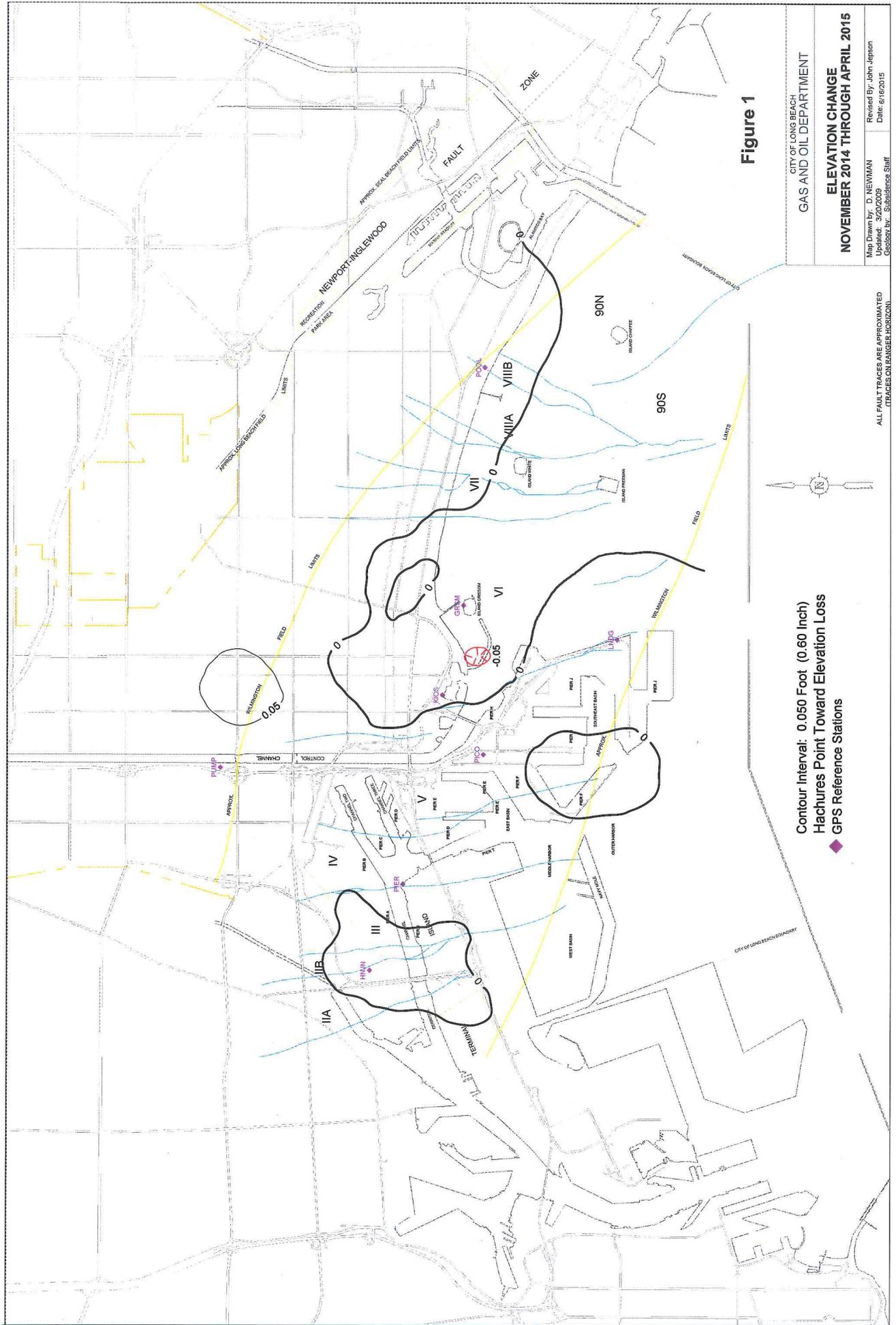


Figure 1

CITY OF LONG BEACH
 GAS AND OIL DEPARTMENT
**ELEVATION CHANGE
 NOVEMBER 2014 THROUGH APRIL 2015**

Map Drawn by: D. NEWMAN
 Operator: S. ZACHARIS
 Checked by: Subsurface Staff
 Revised By: John Jepsen
 Date: 6/16/2015



Contour Interval: 0.050 Foot (0.60 Inch)
 Hachures Point Toward Elevation Loss
 ◆ GPS Reference Stations

ALL FAULT TRACES ARE APPROXIMATED
 BASED ON SURFACE EVIDENCE

