

Engineering Geology and Geotechnical Engineering Aspects of Redevelopment of the Huntington Beach Oil Field, California

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INTRODUCTION

Here I will be review the engineering, geologic and geotechnical engineering aspects of residential development in the Huntington Beach Oil Field. The various constraints to development are directly related to construction practices associated with oil well development and the intrinsic geologic conditions which lead oil producers to the area. Construction practices in the oil field, particularly in earthwork, were not performed to today's rigid standards. Much of the existing residential communities were once oil production sites with derricks, production lines, pumps, and related miscellaneous structures. Figure 1, which is a modified copy of the USGS Seal Beach and Newport Beach (1949) 7.5 minute quadrangles, depicts the density of wells drilled on the Huntington Beach mesa up to that time.

Development of the Huntington Oil Field started in the 1920's, and was the first of the big oil discoveries along the Newport-Inglewood fault zone (Wright, 1987). Numerous town lot subdivisions sprang up, owned and operated by small oil companies. The majority of the oil field was operated by Standard of California, now Chevron. A few small oil companies are still in business today, but many are being squeezed out by the encroachment of residential construction. Huntington Beach was the site of the first large town lot subdivision, which was later surpassed in scope by the 1925 Signal Hill discovery. Over the course of several decades, the oil field has diminished in size due to reduced production levels and residential development boons starting in the 1950's.

SITE DESCRIPTION AND HISTORY

The area of interest lies atop the Huntington Beach mesa, which is one of several mesas along the Newport-Inglewood Fault Zone. Figure 1 shows the approximate limits of this study, which is roughly bounded by Ellis Avenue, Main Street, Seapoint Drive, and the western edge of the mesa. This area was once covered with production wells and even refining facilities starting back as early as 1920. Residential development of the local area started in the 1950's. Of particular interest within the site boundaries was the development of the residential community on the west side of Goldenwest Street and south of Clay Street. This area was developed in the early 1970's. In order to make room for the housing tract, several oil well islands were developed by Chevron. A typical island consisted of approximately 2 to 5 acres and contained numerous directionally drilled wells.

Residential development of several of the well islands and other portions of the site started in 1992. In many of the areas, particularly the islands, earthwork and home construction have been completed and residents have moved in. In other areas, clean-up and removal of contaminated soils have hindered the development process, which has left these areas only partially graded.

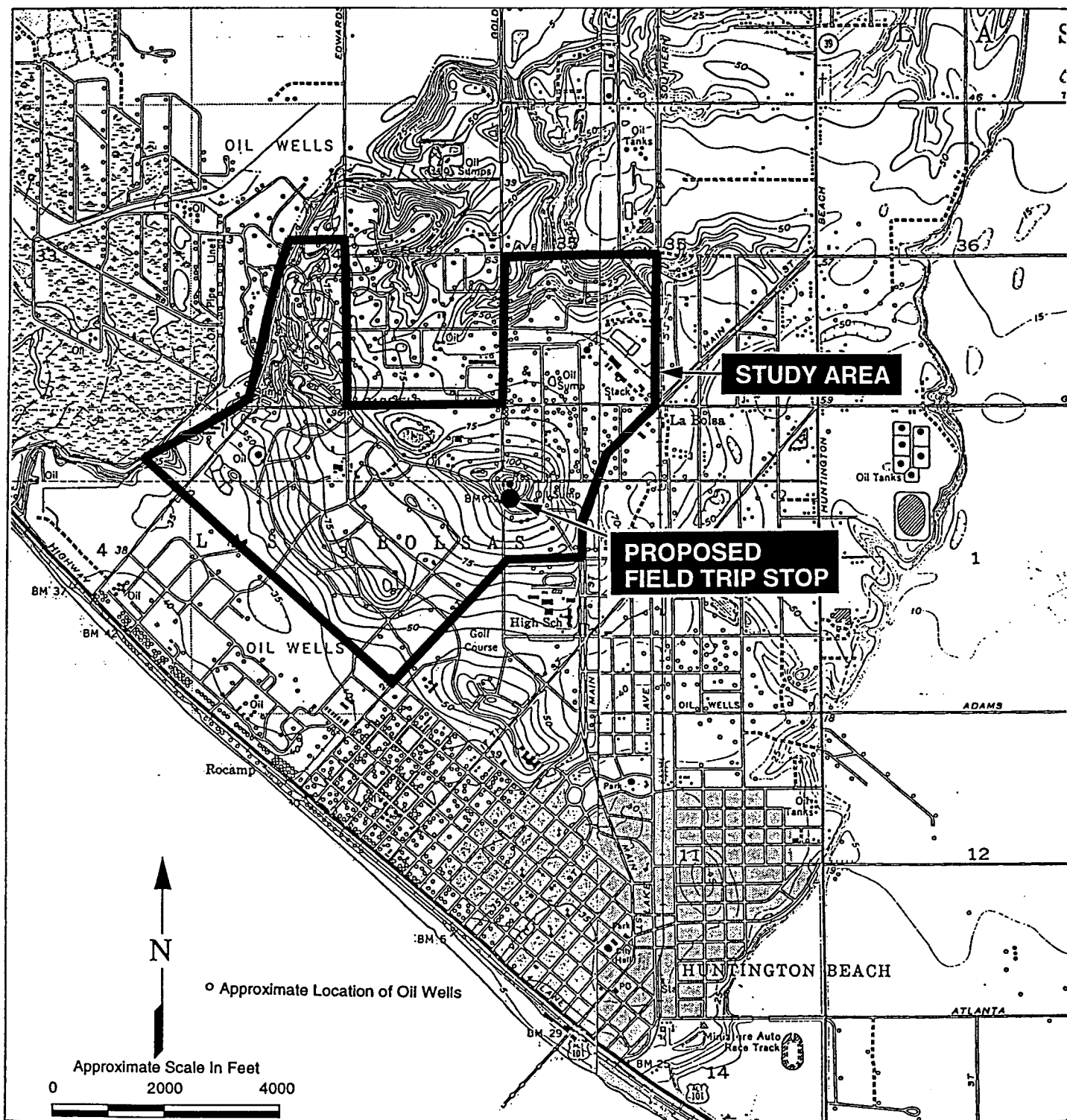


Figure 1. 1949 United States Geological Survey 7.5 Minute topographic map of Newport Beach Calif. and Seal Beach, Calif. showing the study area and field trip stop on Huntington Beach Mesa. Note the many oil well locations.

GENERAL GEOLOGIC CONDITIONS

The Huntington Beach mesa lies within the northwest-plunging Huntington Beach anticline. The Newport-Inglewood fault zone, which trends along the anticlinal axis, transects the mesa. The Newport-Inglewood fault is a northwesterly trending strike-slip fault, which acts as a groundwater barrier and structural oil trap. Several pressure ridges and sag ponds define the trace of the Newport-Inglewood fault on the mesa surface. The highest pressure ridge on the mesa, approximately 125 feet above mean sea level, is at the corner of Goldenwest and Clay Streets. This pressure ridge lines up with two other pressure ridges located north of Yorktown, east of Main, and at the northwest corner of Garfield and Edwards. A large sag pond is located between two of the ridges, southeast of Garfield and Edwards.

Late Pleistocene-age shallow marine sedimentary rocks underlie the near-surface of the mesa and probably correlate to the Harbor and Bent Spring chronozones of Ponti and Lajoie (1992). These sediments typically consist of thinly to thickly bedded very fine to medium sand with silt and occasional fine to coarse gravel. Occasional thin layers of olive gray mud are found interbedded within the sand as distinct laterally discontinuous beds and rip-up clasts. Overlying the majority of the marine sediments is a well developed reddish brown argillic soil horizon, ranging from 4 to 10 feet thick.

The silty clay argillic horizon is a very stiff soil, suitable for light foundation loads, and is slightly to moderately expansive. The silty sands underlying the soil are typically less dense than the soil, but are not prone to excessive collapse. There is also some evidence that portions of the mesa surface were overlain by sand dune deposits. Deposits of very fine sandy silt were encountered in very localized areas during earthwork construction.

GEOTECHNICAL AND GEOLOGIC CONSTRAINTS TO DEVELOPMENT

Many of the geotechnical and geologic constraints that apply to residential development of natural, or undeveloped properties also apply to oilfield redevelopment. In addition to the common constraints are those which specifically apply to oil field redevelopment, including existing and unknown

pipelines and storage tanks, contaminated (hydrocarbon impacted) soils, and abandoned oil wells. Although most of these issues could be described as environmental hazards, they also impact the geotechnical feasibility of development. Other common constraints at the Huntington Beach site include undocumented fills and active faulting. The majority of the development constraints at this site are geotechnical in nature; however, some geologic related constraints are also present. The following sections describe the various constraints, how they impact residential development, and the types of remediation methods that were used at the subject site.

Undocumented Fills

Undocumented fills were found throughout the site and were typically associated with oil pipeline trenches, underground storage tanks, abandoned oil wells, and foundations for oil well development. The oil well islands and the larger parcels were crisscrossed with numerous oil/gas pipeline trenches. Several of the pipeline locations were known; however, many of them were unknown and found during rough grading operations. In many cases, abandoned pipelines were removed and capped at either end along property boundaries. Trench backfill overlying the old pipelines was typically not compacted to modern standards and had to be removed down to natural soil or marine terrace deposits.

Essentially all of the subsurface storage tanks were removed from the various parcels prior to rough grading of the site. Removal operations were done in accordance with the present day environmental standards. In some cases, backfill materials used to replace the void left by tank removal were not properly recompacted and/or never documented. Evidence of this was found on a few of the well islands where after several rain storms, the poorly compacted backfill collapsed and formed small closed depressions on the surface. These areas were identified in the field and the backfill was removed as part of rough grading.

During rough grading operations several buried concrete foundations for oil well drilling and development equipment were unearthed. Concrete piers up to 24 inches in diameter used to support oil well rigging were commonly found in the well islands and within other parcels. Typical rectangular concrete

foundations for pumps and other facilities were also found. These large blocks of concrete were usually removed and hauled off site. The majority of the concrete foundations were broken up with a rock breaker as part of a larger concrete crushing operation that was setup during grading of one of the large parcels.

Abandoned Oil Wells

Numerous oil wells were abandoned as part of the redevelopment. These wells were abandoned per Division of Oil and Gas regulations (Carlson, 1996). Typically the upper 10 feet of soil was removed around the top of the well in order to construct a well vent. Backfill materials overlying the well vent were then placed, in most instances without proper compaction and documentation. As part of the geotechnical observation and testing during rough grading, the backfill around each of the wells was tested. The upper 5 to 6 feet of backfill were usually removed and replaced with compacted fill. In several instances, the backfill was entirely removed and replaced with properly compacted fill.

As part of the well abandonment procedure, well vents were installed over most of the abandoned well heads. Prior to vent installation, a large steel plate was welded onto the top of the well casing. If the abandoned wells fell within 10 to 20 feet of any home, then a well vent was installed. In some instances the well vent was built inside the wall of the closest home and vented through the roof. Each well vent consisted of a 4 feet square by 2 to 3 feet deep gravel base and concrete cap with a PVC open air vent. Prior to backfilling around the vents, air quality measurements were taken and recorded by consultants and government regulators (such as the AQMD).

Hydrocarbon Impacted Soils

In order to regulate the amount of hydrocarbons in compacted soils, the City of Huntington Beach Fire Department adopted ordinances (City Specification 431-92) for fill placement of hydrocarbon impacted soils (HIS). The concentration of Total Petroleum Hydrocarbons (TPH) in near surface soils varied greatly throughout the study area from essentially zero to well over 1000 ppm. Depths and lateral extent of HIS also varied greatly and could not be adequately assessed prior to rough grading of most sites. Removal and

determination of hydrocarbon content of HIS was done by environmental consultants in accordance with the Fire Department guidelines. Removal operations during grading were monitored by both environmental and geotechnical technicians.

Removal of HIS often created deep, steep-sided holes which required replacement with compacted fill. Some removals were about 20 feet deep, which created large differential fill thicknesses across future residential foundations. To lessen the impact of differential fill settlement, two important recommendations were implemented. In order to soften the steep fill transition, the steep sides of each removal excavation were laid back to flatter angles of 26 to 33 degrees from horizontal. Secondly, stiffer foundations were designed to withstand greater differential movement, on the order of one inch in 20 feet (1:240).

Methane Gas

Two methods were employed to control methane gas emitting from abandoned well heads: installation of well vents and thick plastic membranes beneath foundations. The purpose of the control measures was to prevent build-up of methane gas within residential structures. In most cases, air quality monitoring around the wells indicated that little or no methane gas was migrating through the sealed wellheads.

Control of methane gas from wellheads was accomplished by installation of well vents. If an abandoned well fell underneath or within ten feet of a proposed structure, a vent was constructed into a perimeter wall and outletted through the roof. In addition to the well vents, thick plastic membranes were placed beneath the foundations prior to pouring of the concrete slab. After completion of interior utility installation, a thick plastic membrane was placed over the foundation area within the exterior footings. Pieces of membrane were heat sealed along sheet edges and utility pipes rising from the foundation. Upon completion of membrane placement, concrete, sand and then the concrete foundation were placed.

Active Faulting

Due to the relatively flat surface of the mesa, there were few geologic constraints associated with development of the site. The North Branch Fault of the Newport-Inglewood fault zone was the major geologic

constraint to home construction. Regulatory statutes do not allow construction of habitable structures across an active fault trace. The Alquist-Priolo Earthquake Fault Zoning Act, enacted in 1973, includes the definitions and guidelines required for residential construction within an active fault zone (Hart, 1994). Several investigations by many different engineering geologic consultants were performed for the site.

Substantial evidence was found to suggest that the North Branch fault of the Newport-Inglewood fault zone offsets Holocene-age soils. In one particular area, midden deposits, ranging in age from 2,000 to 5,000 years before present (ybp), were offset by a minor splay of the North Branch fault. Evidence of secondary faulting was also uncovered during removals of a small landfill site.

Each strand of the North Branch Fault was located and surveyed as part of the initial development studies. Based on the survey locations, building setbacks, approximately 50 feet from each side of the fault zone, were established to assist the developer in designing lots and land uses along the fault zone. Fault investigation studies were hampered by HIS which made trenching unsafe due to odors, and also discolored the soils making it difficult to discern the various geologic units.

SUMMARY

Residential development of the Huntington Beach Oil Field began in the 1950's, during a time of little regulation from both a hazardous materials and geotechnical viewpoint. Since then strict regulations regarding the removal and replacement of hydrocarbon impacted soils (HIS) have been established and were implemented during residential construction in the 1990's.

Earthwork practices used during oil field operations resulted in the creation of significant hazardous materials and geotechnical constraints to residential development. Geotechnical constraints were typically associated with the removal of uncompacted fill materials covering pipelines, underground storage tanks, and abandoned oil wells. Removal and recompaction of the materials usually mitigated the problems. Deep removal of HIS resulted in differential settlement of compacted fill materials placed in the deep removal areas. Side slopes of deep removals were laid back in order to lessen the amount of settlement, and

stiffer foundations were designed to accommodate for larger settlements.

In addition to addressing the removal of HIS, the migration of hydrocarbon related gases such as methane were controlled by installing well vents and placing thick plastic membranes beneath foundations. Well vents were installed along the outside walls of residential structures and vented to the open air.

Active faults are common in oil field property and present a constraint to residential development. The Huntington Beach Oil Field is transected by the Newport-Inglewood fault zone, which is considered active by the State Mining and Geology Board (Hart, 1994). In order to address the impact that active faulting might have on the development, several trenches were excavated across the fault zone. The numerous fault splays were identified and a building set back was established to prevent damage to structures from ground rupture.

REFERENCES CITED

- Barrows, A.G., 1974, A Review of the Geology and Earthquake History of the Newport-Inglewood Structural Zone, Southern California: California Division of Mines and Geology, Special Report, p. 114, 115.
- Bryant, W.A., 1988, Recently active traces of the Newport-Inglewood Fault Zone, Los Angeles and Orange Counties, California: California Division of Mines and Geology, Open-File Report, p. 88-14, 15.
- Carlson, K. M., 1996, Oil Fields in Transition - A Look at California's Oil Well Plugging and Abandonment and Construction Site Plan Review Programs, *in* Clarke, D. D., Otott, G. E., and Phillips, C. C., Old Oil Fields and New Life: A Visit to the Giants of the Los Angeles Basin, Guidebook, Division of Environmental Geology, Pacific Section, American Association of Petroleum Geologists, and the Society of Petroleum Engineers, in press.
- Hart, E. W., 1994, Fault Rupture Hazard Zones in California: California Division of Mines and Geology, Special Publication 42, 34 p.
- Ponti, D.J., and Lajoie, K.R., 1992, Chronostratigraphic Implications for Tectonic Deformation of Palos Verdes and Signal Hills, Los Angeles Basin, California, *in* Heath, E.G.,

and Lewis, W.L., eds., The Regressive
Pleistocene Shoreline, Coastal Southern
California: South Coast Geological Society,
Guidebook no. 20, p. 157-160.

Wright, T., 1987, Petroleum Development in the Los
Angeles Basin, a Historical Perspective, *in*
Wright, T., and Heck, R., eds., Petroleum
Geology of Coastal Southern California: Pacific
Section American Association of Petroleum
Geologists, Guidebook 60, p. 57-65.