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Site of an Oil-Producing Property

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SYNOPSIS: An assessment of a 6.78-acre parcel of oil-producing land with one active, seven idle, and two abandoned oil wells was performed. Following the collection and review of site data, an evaluation was made of the toxic properties of on-site soils for the presence of hazardous substances. Soil samples were collected by advancing boreholes at eight locations. These locations were selected on the basis of the results of an aerial photographs review, a geophysical survey, and statistical sampling design techniques. An analytical program was conducted to test for chemicals that would likely be present from the oil field operations.

It was concluded that the on-site soils are not hazardous. However, soils contaminated with petroleum hydrocarbons were identified. A soil gas survey was performed to evaluate the presence of methane and other hazardous gases. Based on the results of the survey, recommendations for reducing the adverse effects of such gases were developed, which were incorporated into the design of the building foundations. A soil remediation plan was developed and approved by the regulatory agencies. The contaminated soils were excavated, blended with clean soils, and recompacted under areas to be paved. The existing oil wells were abandoned, and the previously abandoned wells were re-abandoned in accordance with the applicable standards.

INTRODUCTION

A site assessment was conducted for a property, 6.78 acres in area, located in the City of Santa Fe Springs, California. The location of the site is shown in Figure 1. The site is located within the Santa Fe

Springs Oil Field. At the time of the investigation, the site was being considered for development of eight two-story industrial buildings.

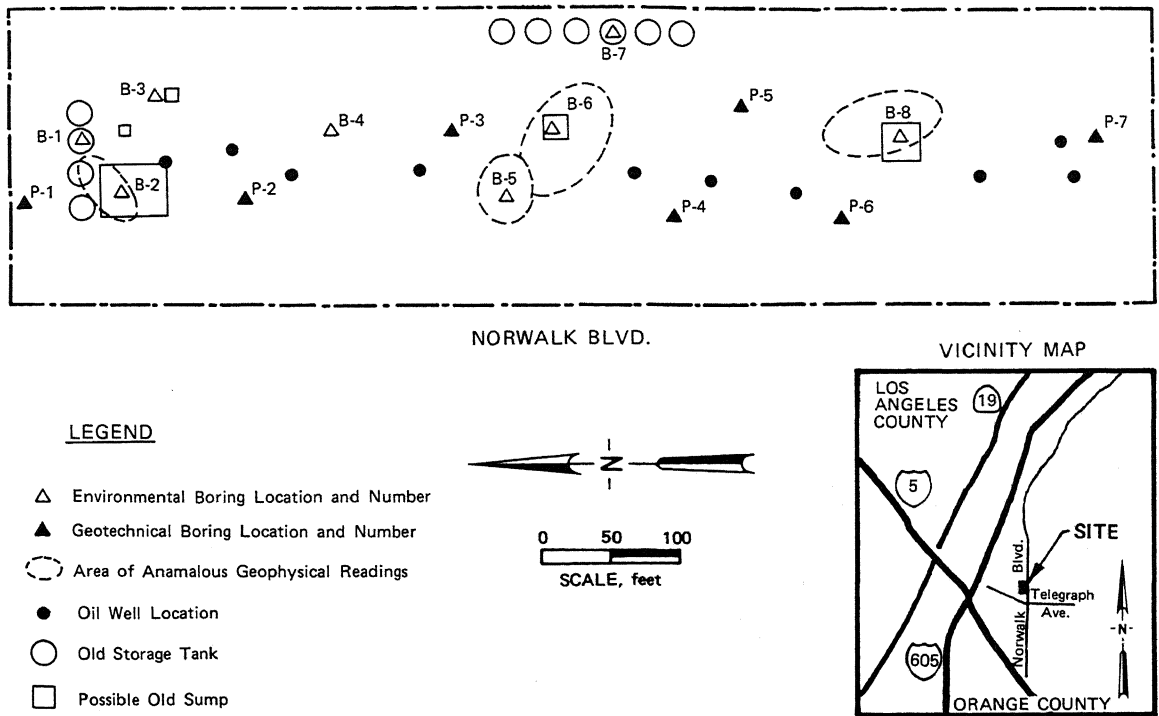


FIGURE 1 - SITE AND BORING LOCATION PLAN

Geologically, the area is underlain by about 7,000 feet of Pleistocene sediments and sedimentary rocks, below which the Miocene units occur. The upper 200 to 300 feet of the sediments are generally sand and gravel with some clay underlain by hard shale and boulders. The shallow materials, revealed in borings drilled on-site to a depth of 46 feet, generally consist of sand, silty sand, sandy silt, and some clayey materials in the upper 20 feet underlain by generally dense gravelly sand and fine gravel.

The depth to ground water is about 60 feet in a well maintained by the City of Santa Fe Springs, located about one-half mile northeast of the site. The depth to ground water in three wells located about one mile south of the site reportedly ranges from 92 to 100 feet.

At the time of the investigation, there were no buildings at the site. The site was leased to a major oil company for production and storage of crude oil. Oil storage tanks did not remain on the site. There were eight visible oil wells at the site. Seven of these were idle, with the oil production facilities dismantled and the well heads capped above ground. The Santa Fe Springs Oil Field Map (California Division of Conservation, Department of Oil and Gas, Sheet No. 102, 1985) indicated that there were two abandoned oil wells on-site. The approximate locations of the oil wells are shown in Figure 1. Several abandoned and active pipelines crossed the site.

METHODOLOGY

The site assessment was comprised of the following three phases:

- Phase I: Environmental site appraisal
- Phase II: Site characterization and assessment
- Phase III: Development of remedial measures

The objective of the Phase I study was to identify areas within the site that may be contaminated. Accordingly, the scope of the Phase I study was planned to respond to the following question:

Considering the past land-use history, are there likely to be hazardous materials at the site and, if so, within which areas of the site?

The objective of the Phase II investigation was to study the characteristics of the site materials for the presence of hazardous materials at areas within the site identified in the Phase I study. It was considered cost-effective to conduct the Phase IIa investigation in two sub-phases. Using this approach, the scope of initial Phase II investigation was designed to respond to the following question:

Are the materials in the investigated areas hazardous or non-hazardous as defined under the applicable laws?

If hazardous materials were discovered during the initial Phase IIa effort, a supplementary Phase IIb sampling and analysis would be required to address the following additional issue:

What are the nature and lateral and vertical extent of contamination?

Developing mitigation measures, consisting of in-situ, on-site, and/or off-site remedial alternatives would be part of the Phase III investigation, if mitigation was required.

ENVIRONMENTAL SITE APPRAISAL

The environmental site appraisal included the following efforts:

- o Site visits;
- o Interviews with staff of the oil company leasing the site;
- o Review of oil well records;
- o Review of historical aerial photographs;
- o Performing a geophysical survey; and
- o Preparing a Phase II work plan.

A literature search showed that the Santa Fe Springs Oil Field was discovered in 1919 (Ybarra, 1957). Intensive drilling campaigns were undertaken in 1921-23 and again in 1928-29. The wells were drilled with rotary drilling equipment. The site history review showed that the site was used as a chicken farm prior to 1920, but environmental impairment was not suspected from that activity. No commercial or industrial uses other than normal oil field and crude oil storage operations were suspected.

Available historical aerial photographs were reviewed. Two old above-ground storage tank areas and several features appearing to be sumps were identified. The locations of these features are shown in Figure 1.

Geophysical Survey

A geophysical terrain conductivity survey was conducted to identify areas within the site exhibiting anomalous conductivity values. A region of anomalous values is generally associated with unusual soil conditions, such as the presence of petroleum products. The presence of metallic conductors, such as buried tanks, pipelines or metallic debris would also cause distinctive anomalous values. The results of this type of survey are generally useful in locating areas underlain by metallic objects or previously used as sumps.

Geonics EM-31 conductivity meter was used to conduct the survey. The Geonics EM-31 is a one-man, portable instrument, and has a depth of penetration of about 19 feet. Measurements were taken continuously and, due to the freedom from wires and direct ground contact, the technique provided a rapid means of site evaluation.

Initial reconnaissance at the site revealed several underground pipelines and metallic debris. Four geophysically anomalous areas, shown in Figure 1, were identified.

Site Investigation Work Plan

Based on the site's land-use history, on-site chemical contaminants were believed to include drilling fluids, spilled crude oil, metals from paint or tank oxidation, and tank-bottom sludges. A preliminary evaluation of possible sources of soil contamination at the site identified oil wells, above-ground storage tank sites, old sumps, and oil pipelines as areas of suspected environmental hazards.

Phase II investigation plan (work plan) was developed. The scope of the investigation was designed only with respect to soil contamination, and not for evaluating the possibility of ground water contamination, as the possibility of ground water contamination does not appear to be great. Data from existing water wells located less than one mile from the site show the ground water to be at depths ranging between about 60 and 100 feet below ground surface.

The numbers and locations of the soil borings were selected on the basis of the following considerations:

- Areas identified on historic aerial photographs as possible old sumps;
- Areas identified in the geophysical survey as exhibiting anomalous conductivity values; and
- Statistical sampling design techniques, which allowed assigning confidence levels to the results of the sampling program.

The work plan included the following information:

- Location and depth of soil samples;
- Sampling procedures, including drilling and sampling methods, sample collection procedures, auger and sampling equipment decontamination, documentation and chain-of-custody procedures, procedures for handling of drill cuttings and steam cleaning waste water, and back-filling of boreholes;
- Chemical analyses procedures and criteria for selection of chemical analyses and soil samples to be analyzed;

- Quality Assurance/Quality Control (QA/QC) procedures; and
- Health and safety precautions during field activities.

FIELD AND LABORATORY INVESTIGATION

The field investigation program consisted of drilling boreholes, collecting soil samples, and performing laboratory analyses. For selecting the sampling locations, it was noted that if the site is clean, then none of the collected soil samples would show contamination. In contrast, if the site is actually contaminated, some of the collected samples may not detect contamination. Realizing this uncertainty in results, it was decided to design a sampling program that was likely to provide a 95 percent confidence in results. With this stipulation, it was calculated that eight borings were needed to detect contamination. Consequently, eight boring "sites" were selected in areas of the property identified as possible sources of soil contamination: four in the old sump areas, two in the old storage tank areas, one in proximity of oil wells, and one in the oil pipeline areas. Within each boring "site," the boring location was obtained by randomization.

The locations of the eight borings are shown in Figure 1. Two of the borings, B-2 and B-6, were advanced to a depth of 46 feet, and the remaining six to a depth of 22.5 feet. Drilling was performed using an 8-inch outside diameter hollow-stem auger. Soil samples were collected using a modified California split-spoon sampler that contained four brass tubes. All borings were sampled at depths of 1, 5, 13, and 21 feet. The two deeper borings were additionally sampled at 29, 37, and 45 feet.

Fifteen surface samples were collected from locations selected based on oil staining, discoloration, and/or odor. The samples were collected by scooping soil from a depth of 6 to 12 inches using a stainless steel trowel. The samples were placed in glass jars.

As part of the geotechnical investigation program (performed subsequent to the site assessment investigation), seven borings, designated in Figure 1 as P-1 through P-7, were drilled. During the drilling of Boring P-3, hydrocarbon odor was noticed at depths between about 3 and 20 feet. Soil samples from these depths were analyzed in the laboratory for total petroleum hydrocarbons.

The soil samples collected as part of the site assessment investigation were screened for laboratory analysis on the basis of visual observations, odor or field readings obtained on the Organic Vapor Meter (OVM) or HNu. Composite samples were prepared in the laboratory by combining approximately equal volumes of soil taken from the brass tubes or glass jars containing field samples. Compositing of subsurface samples was limited to samples collected from the same boring.

The analytical parameters were selected considering the requirements of Article 11, Chapter 30, Title 22 of the California Administrative Code for assessment of hazardous properties of on-site materials, as described below under Assessment Methodology. Since the land-use history review had indicated that no materials from other than oil production and storage operations were likely to be found at the site, it was assumed that the only hazardous property of concern is toxicity. Therefore, the program was designed to identify hazardous materials on the basis of toxicity. The analytical program did not test for other physical and chemical characteristics like corrosivity, ignitability or reactivity.

The test samples were analyzed for:

- Total petroleum hydrocarbons using infrared spectrometry, EPA Method 418.1;
- Total metals (arsenic, barium, cadmium, total chromium, copper, lead, mercury, nickel, vanadium, and zinc) using Inductively Coupled Plasma/Mass Spectrometry (ICP/MS);
- Extractable metals using 48-hour citric acid extraction by California Waste Extraction Test (WET);
- Volatile and semi-volatile (base-neutral/acid extractable) organic priority pollutants by Gas Chromatography/Mass Spectrometry (GC/MS) using EPA Methods 8240 and 8270, respectively;
- Head space vapor analysis (for inhalation toxicity) by GC/MS using EPA Method 5020; and
- Aquatic (fish) toxicity using California Waste Assessment Bioassay procedures.

QUALITY ASSURANCE/QUALITY CONTROL (QA/QC)

A quality assurance program, was followed throughout the investigation. The QA/QC procedures followed in the field included calibration of the OVM and HNu, standard sample handling, and standard quality control documentation procedures. Chain-of-custody forms, labels, data forms, and field logbooks were used.

The QA/QC program performed in the chemical laboratories consisted of the following procedures:

- Initial calibration of instruments;
- Periodic recalibration of instruments during analytical work;
- Analysis of preparation blanks;
- Analysis of interference check samples;
- Analysis of spiked samples;

- Analysis of duplicate samples; and
- Performance of standard QA/QC procedures.

ASSESSMENT METHODOLOGY

In California, the Hazardous Waste Control Law (Health and Safety Code, Chapter 5.6, Division 20) and hazardous waste regulations (Chapter 30, Division 4, Title 22 of the California Administrative Code) provide for a program to ensure safe handling, storage, use, processing, and disposal of hazardous wastes, and recovery of resources from hazardous wastes. The California Administrative Code (CAC), as supplemented by the California Administrative Register, is an official publication of the State of California. The California Department of Health Services uses Chapter 30 (Minimum Standards for Management of Hazardous and Extremely Hazardous Wastes), Division 4 (Environmental Health), Title 22 (Social Security) of CAC for identification of hazardous materials. For evaluations made in the present site assessment, current revisions to the CAC were considered.

A "hazardous material" is defined in Chapter 30, Title 22 of the CAC as:

" . . . a substance or combination of substances which, because of its quantity, concentration, or physical, chemical or infectious characteristics, may either; (1) cause, or significantly contribute to an increase in mortality or an increase in serious irreversible, or incapacitating reversible, illness; or (2) pose a substantial present or potential hazard to human health or environment when improperly treated, stored, transported or disposed of or otherwise managed."

Criteria utilized for identification of hazardous materials include toxicity (including persistent and bioaccumulative properties), corrosivity, ignitability, and reactivity. Acute toxicity is considered in terms of the lethal dose and concentration for 50 percent of a population of specified laboratory animals (LD₅₀ and LC₅₀, respectively). According to Kenaga (1986), dosage is the amount of chemical applied directly to an organism. The LD₅₀ is the dosage of a chemical that will cause 50 percent mortality in a given test species. A concentration applied to a given medium, such as water, soil or food, results in uptake of a certain amount by an organism. The LC₅₀ is the concentration in the medium that results in 50 percent mortality of a given test species of test organism. Toxicity values are commonly expressed in terms of milligrams of chemical per kilogram of body weight of the organism tested. To arrive at this toxicity value, LD₅₀ values do not need conversion. However, LC₅₀ values must be converted by such values as the bioconcentration factor or dietary intake rate to calculate milligrams of toxicant per kilogram of body weight (Kenaga, 1986).

According to the criteria specified in Article 11, Chapter 30, Title 22 of the CAC, a waste, or a material, is toxic and hazardous if it:

- Has an acute oral LD₅₀ less than 5,000 mg/kg; or
- Has an acute dermal LD₅₀ less than 4,300 mg/kg; or
- Has an acute inhalation LC₅₀ less than 10,000 ppm as a gas or vapor; or
- Has an acute aquatic 96-hour LC₅₀ less than 500 mg/l; or
- Contains any of the 16 organic substances listed at a single or combined concentration equal to or exceeding 0.001 percent by weight; or
- Has been shown through experience or testing to pose a hazard to human health or environment because of its carcinogenicity, acute toxicity, chronic toxicity, bioaccumulative properties or persistence in the environment; or
- Is listed in 40 CFR 261 (Code of Federal Regulations, 1982) as a hazardous waste.

For persistent and bioaccumulative toxic substances, two threshold limit values are specified. The higher value is the Total Threshold Limit Concentration (TTL), and the lower value is the Soluble Threshold Limit Concentration (STLC). Lists of specified STLCs and TTLs for 20 inorganic and 16 organic persistent and bioaccumulative toxic substances (metals, pesticides, and PCBs) are provided in Article 11. A waste listed in Article 11 is considered hazardous if its total concentration exceeds its specified TTL or its soluble concentration exceeds its STLC.

RESULTS OF SITE ASSESSMENT

The results of total petroleum hydrocarbons analyses showed that five soil samples contained concentrations exceeding 1,000 mg/kg up to 6,400 mg/kg. These samples were collected from depths between 13 and 21 feet in Boring B-6 and from depths between 3 and 15 feet in Boring P-3.

The total concentrations of the ten metals analyzed were below the TTLs of the metals. One composite sample exceeded the STLC of arsenic and three other composite samples exceeded the STLC of lead. The discrete samples making these composite samples were analyzed by the California Waste Extraction Test (WET) for extractable (soluble) concentrations of arsenic and lead. The soluble concentrations were below the STLCs of arsenic and lead (5.0 mg/l).

Test samples were analyzed for the presence of volatile and semi-volatile organic compounds.

Volatile organic compounds were also measured in the head space vapor of the test samples for inhalation toxicity assessment. Organic chemicals found in the test samples and their maximum concentrations in ppm were: ethylbenzene (0.7), fluorene (0.9), 2-methylnaphthalene (11.0), naphthalene (4.3), phenanthrene (1.7), toluene (13), and xylenes (111). The analytical data also indicated the presence of undifferentiated C9-35 aliphatic hydrocarbons at concentrations up to 1,000 ppm and C9 aromatic hydrocarbons at concentrations up to 168 ppm.

For the organic chemicals identified in the test samples, published oral and dermal acute toxicity estimates derived from laboratory tests on mammals were obtained from Tatken and Lewis (1983), Lewis and Sweet (1984), Clayton and Clayton (1979), Sax (1979), and Union Oil Company (1982). Using the published oral and dermal acute toxicity values and the waste mixture formula given in Article 11, Title 22 of the CAC, the lowest calculated oral and dermal LD_{50s} were found to be greater than 5,000 and 4,300 mg/kg, respectively.

Concentrations of the materials in the head space vapor of the test samples were calculated, and were compared to published acute inhalation toxicity estimates obtained from the literature cited in the preceding paragraph. The results showed that the materials in the head space vapor of the test samples had acute inhalation LD_{50s} greater than 10,000 ppm.

Aquatic toxicity tests were performed on selected test samples. Fish mortality was not observed during the exposure periods.

Following the assessment criteria described under Assessment Methodology, it was concluded that the materials contained in the test samples are not hazardous. However, it was recommended that soils with concentrations of total petroleum hydrocarbons exceeding 1,000 mg/kg be excavated and remediated on-site, as described under Soil Remediation.

SOIL GAS SURVEY AND METHANE GAS MITIGATION

Since the fire and explosion incidence, which occurred in March 1985 in Ross Stores of the Fairfax area of Los Angeles, and, which is believed to have been caused by gas seeping from a natural accumulation of gas from the soil, there has been increased concern in southern California regarding the accumulation of methane and other hazardous gases within oil fields. As noted by GeoScience Analytical, Inc. (1986), gas accumulation can be the result of seepage from abandoned wells, natural petroleum or gas seeps or shallow biogenic gas (resulting from bacterial activity). Methane can also be the result of thermogenic (heating) processes and can resemble biogenic gas in composition.

To investigate the presence of methane at the site, a soil gas survey was conducted. The soil gas survey technique is based on the

premise that many Volatile Organic Compounds (VOCs) will volatilize from contaminated soils. VOCs move as vapors (gas phase) by molecular diffusion away from source areas, toward regions of lower concentration in the overlying and surrounding soil profile. They also move in response to pressure gradients, to the extent these exist in the soil column. As the VOCs degrade, other biogenic byproducts such as methane may also be generated. Soil gas survey is used in an attempt to identify areas of high soil gas concentration as a means of broadly delineating the zones of soils containing volatile constituents.

Soil gas probes were installed at seven locations. The locations were selected to cover the site area underlying the proposed buildings. At the time of the survey, the subsurface soils appeared to be wet. At each probe location, a probe was driven to depths of about 4, 8, and 12 feet. The probes are 1/2-inch galvanized steel pipes, perforated over the bottom 9 inches. The probes were driven using a post-driver and a compressor.

A suction pump removed subsurface soil vapor through the probes. The removed vapors were monitored using a Century System Model 128 Organic Vapor Analyzer (OVA) with a flame ionization detector. The OVA is capable of detecting most VOCs encountered in the field. The range of the measurement of the OVA is 0 to 1,000 ppm.

OVA readings were taken generally after pumping periods of 1, 5, and 10 minutes for the 4-, 8-, and 12-foot probe depths, respectively. These periods approximately correspond to the lengths of time required to remove equal volumes of gas from the probes.

The results of the OVA readings indicated that except for one probe, the OVA readings at all depths were 20 ppm or lower. At one probe, installed at a location half-way between Borings B-5 and P-3, the readings were in excess of 1,000 ppm at the 4- and 12-foot depths and about 360 ppm at the 8-foot depth. No trend of increasing or decreasing gas concentrations with depth is indicated by the data. These readings are considered to be relatively high, although it should be noted that gas accumulation rates can vary significantly depending on soil's moisture content temperature, changes in paved surfaces, and changes in conditions of oil wells (e.g., abandonment).

Based on the results obtained and considering the requirements of the County of Los Angeles and the City of Santa Fe Springs, it was recommended that measures to mitigate the potential hazards from accumulation of methane and other hazardous gases at the site be included in the development of the site. The mitigative measures described below were performed prior or during the construction of the buildings:

1. Unabandoned oil wells were abandoned and previously abandoned oil wells were re-abandoned in accordance with current

re-abandonment requirements of the California Department of Conservation, Division of Oil and Gas.

2. On-site pipelines were removed. Soil adjacent to the pipelines observed to be contaminated on the basis of discoloration, oil-staining or odor was excavated. The excavated soil was treated according to the remediation procedure described in the following section.
3. To minimize accumulation of methane and other hazardous gases in the buildings, the following methane gas mitigation measures were implemented:

- The foundations were sealed with 30-mil layers of reinforced chlorinated polyethylene below the concrete slab-on-grade; and
- Perforated 4-inch diameter vent pipes, laid in gravel trenches, were installed to collect and vent the accumulated gases from beneath the sealed foundations.

SOIL REMEDIATION

Soils containing high concentrations of total petroleum hydrocarbons were remediated following the preparation of a soil remediation plan. This plan was approved by the California Department of Health Services and implemented by the oil company leasing the on-site oil wells. The remediation operations were directed, observed, and documented by Woodward-Clyde Consultants.

The general procedure described below was followed in remediating the oil-contaminated soils:

1. A pit measuring approximately 85 by 150 feet in area and 15 to 25 feet deep was excavated in the general area surrounding Borings B-6 and P-3. Soil excavation stopped when concentrations of total petroleum hydrocarbons, as measured by EPA Method 418.1, were below 1,000 mg/kg.
2. Excavated soil was aerated by spreading it on the ground for several hours and plowing it a few times. This process was found to be helpful in reducing the concentration of petroleum hydrocarbons.
3. Aerated soil was blended with clean soil excavated from on-site areas to further reduce the concentration of petroleum hydrocarbons.
4. Blended soil was stockpiled on-site and was mixed and aerated periodically.

5. Stockpiled soil was placed in areas of the site designated for paved street and parking. Prior to placement, samples of the stockpiled soil were analyzed by an on-site mobile laboratory to verify reduction of total petroleum hydrocarbons to below the 1,000 mg/kg cleanup action level.
6. The excavated pit was backfilled and compacted. Prior to backfilling, soil samples were collected from the bottom and walls of the pit and analyzed to verify that they did not contain total petroleum hydrocarbon concentrations in excess of 1,000 mg/kg. Clean on-site soil was used for backfilling those parts of the pit underlying the areas designated for the buildings. Stockpiled (treated) soil was used for backfilling areas of the site designated for paved street and parking.

The excavation, aeration, blending, and mixing operations were accomplished using one CAT 613B scraper, one J.D. 860B scraper, one IH D50C track-mounted loader, and one IH D-20 dozer. All excavated soils were continuously sprayed with a 1,000-gallon water truck to minimize dust. Compaction was performed by a rubber-tire roller and/or by track rolling using the scrapers or the loader.

CONCLUSIONS

As available land for development becomes scarce, potentially contaminated sites within oil fields become attractive for development. These sites are generally used for production and storage of crude oil only; however, a historical evaluation of the site should confirm this. A site assessment investigation needs to be performed to investigate the presence of hazardous substances. A remediation plan that addresses mitigation of hazardous materials, oil contaminated soil, and sump materials, if present, should be prepared and implemented. The potential for accumulation of methane and other hazardous gases should be minimized by implementing appropriate measures.

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