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STAGE 1 & 2 REPORTS

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April 11, 2003

HAYNES AND BOONE, LLP

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ENVIRONMENTAL BUREAU
OIL CONSERVATION DIVISION

William C. Olson
New Mexico Oil Conservation Division
P. O. Box 6429
Santa Fe, New Mexico 87504

RE: Case No. CV-99-00509-L; *Concepcion and Rosario Acosta, et al. vs. Shell Western E&P Inc.*; In the Fifth Judicial District Court, County of Lea, State of New Mexico

Dear Bill:

On April 16, 2003 we received the enclosed "Summary of Contamination, Westgate Subdivision, Hobbs, New Mexico." Because the report appears to be highly critical of our assessment and remediation work in the Westgate subdivision – and includes allegations of numerous violations of NMOCD "regulations" – I thought you might like to have a copy of the report.

Regards,

HAYNES AND BOONE, LLP

Michael J. Mazzone
MJM/mgr

Enclosure

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SUMMARY OF CONTAMINATION
WESTGATE SUBDIVISION
HOBBS, NEW MEXICO

Prepared for:

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Acosta v. Shell Western Exploration
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April 11, 2003

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Environmental Science & Technology

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1. INTRODUCTION

Hydro Geo Chem, Inc. (HGC) is pleased to submit this summary of past environmental investigations and data pertaining to the Westgate Subdivision in Hobbs, New Mexico. This report was prepared from existing data reports, aerial photography, a site visit, and additional information provided to HGC by Girardi and Keese, LLC. The expert opinions expressed in this report regarding the information reviewed are those of Mr. Mark W. Kuhn, Executive Vice-President of HGC, whose resume is included in Appendix A. A complete list of the documents reviewed by HGC is provided in Appendix B. New Mexico Oil Conservation Division (NMOCD) regulations are provided in Appendix C and references compiled and cited in Section 3 are provided in Appendix D. Shell's primary environmental consultants for the remedial investigations described below were Philip Services Corporation (PSC) and BBC International (BBC), whose reports were heavily relied upon for information.

1.1 Subdivision Construction History

Historically, land the Westgate subdivision now occupies and adjacent property to the north and west was used for crude oil production. The Hobbs oil pool was discovered in 1928. Figure 1 shows the boundaries of the Westgate subdivision superimposed on a 1949 aerial photograph that shows crude oil production activities. The area shown in Figure 1 is primarily the southern one-half of Section 28, Township 18 South, Range 38 East, in Lea County, New Mexico. The portion of the area that is the subject of this report (the site) consists of the residential and undeveloped properties indicated on Figure 1. The site is now (2003) bordered by residential homes on the north side of Princess Jeanne Drive and Sanger Street on the south, and consists of the homes along Tasker Drive and Cobb Drive, and a strip of undeveloped land immediately west of the housing development (Figure 1). Detailed information regarding precisely when each home in the subdivision was constructed or inhabited has not been reviewed in this report. The general sequence of housing development described in the following sections has been inferred from aerial photographs. Dates of property ownership changes can be obtained from the Lea County assessors office, but those details are outside of the scope of this report. The 1949 photograph underlying the subdivision outline in Figure 1 (PSC & BBC, 1998) shows no residential housing development in the area of the site. Figure 1 shows the subdivision outline with current and historical oil production wells as well as the location of the Grimes tank battery, at the southern end of Cobb Drive.

A 1954 aerial photograph (PSC & BBC, 1998) shows residential housing construction in the Westgate subdivision north of Berry Drive, south of Princess Jeanne Drive, east of Pennington Street and west of Grimes Street, with the surrounding areas continuing to be used for oil production. A 1964 aerial photograph (PSC & BBC, 1998) shows residential housing construction spanning from Grimes Street to San Andres Drive north of Sanger Street and south of Princess Jeanne Drive in the midst of oil production wells and the Grimes tank battery. No grading or construction activities were observed on Tasker Drive or Cobb Drive (within the site boundaries) in the 1964 photograph.

A 1978 aerial photograph (PSC & BBC, 1998) depicted residential development on Tasker Drive north of Berry Drive (within the site boundaries). The preparatory grading of residential lots on the east and west sides of Cobb Drive are shown in the photo, but no housing construction is evident. Ten years later, a 1988 aerial photograph (PSC & BBC, 1998) shows new home construction south of Berry Drive on the east side of Tasker Drive. Although the lots had been graded, no additional dwellings had been constructed by 1988 on the west side of Tasker Drive south of Berry Drive, with the exception of a single dwelling on the southwest corner of the Berry Drive and Tasker Drive intersection. Dwellings are present on the east and west sides of Cobb Drive north of Berry Drive in the 1988 aerial photo, immediately adjacent to the Grimes tank battery.

1.2 Grimes Tank Battery

The Grimes tank battery was put into service in 1946 and decommissioned in 1993 under the ownership of Altura Energy, Ltd. (PSC & BBC, 1998). The Grimes tank battery site consists of oil production wells, salt water and crude oil storage tank batteries, and associated pipelines. Table 1 summarizes a compilation of production data from the Oil & Natural Gas Administration and Revenue Database (ONGARD) performed by Stone Lions (2003). The earliest records in the database date back to 1972. Since that time, the database reports that 170,849,238 gallons of oil have been produced from the wells shown on Figure 1 since 1972. This corresponds to 11 gallons per minute (gpm) of sustained oil production for every minute from 1972 until 2002, the 30 year period reported in ONGARD. The wells also produced 6,271,978 million cubic feet (MCF) of natural gas, and approximately 1.5 billion gallons of water (100 gpm sustained), according to database records. Assuming oil production began in 1928, these production numbers probably represent about one-half of the total fluid production to date from the portion of the Hobbs oil pool located in the southern half of Section 28.

The fluids produced from these wells were piped to the Grimes tank battery. Oil produced from the battery was transported south in a pipeline owned by Shell. Little indication of the extent of water and gas storage and processing infrastructure was provided in the reports reviewed by HGC. The number and locations of oil transmission pipelines in the vicinity of the site are also unknown. Based on the extensive land disturbance beginning in the 1949 aerial photograph, the piping networks, circuits, and fluid handling facilities were extensive. The Hobbs oil pool was sufficiently productive that production data was incorporated into the ONGARD database beginning in 1972, 20 to 40 years after significant production began. Data through 2002, the last year of record in ONGARD, shows that many wells are currently producing as much oil as they were in 1972.

2. HISTORY OF ENVIRONMENTAL EFFORTS

This section describes, in chronological order, the various environmental activities performed at the site. Historical laboratory analytical reports admitted to the record have been reviewed and summarized in Tables 2 through 6. Copies of the laboratory analytical reports, therefore, have not been included with this report. Figure 2 shows areas of historical surface excavation conducted in attempt to remediate soil contamination. Figures 3 through 7, which show locations of various environmental sampling points, have been compiled from numerous maps included in the references.

2.1 Site Hydrogeology

Depth to groundwater was approximately 65 feet below land surface (ft bls) in 1998, and groundwater flow was toward the south/southwest (PSC & BBC, 1998). Subsurface geology in the area consists of hard, buff colored limestone to 15 ft bls, underlain by tan predominantly fine-grained sandstone with trace amounts of red sandstone, chert, and limestone (PSC & BBC, 1998). Lithological logs indicate that the surficial soil consist of highly permeable fine-grained sands extending to a depth of 5 to 8 ft bls. At several locations in the soil horizon, siliceous limestone was intermixed with the fine sand (PSC & BBC, 1998).

2.2 Altura Energy Remediation 1997

Altura Energy, Ltd. removed tanks, equipment, and contaminated soil from the Grimes oilfield tank battery in 1997 (PSC & BBC, 1998). During this period, Altura excavated a significant amount of soil in the area of a former emergency overflow storage pit (Figure 2). Soil was excavated to a depth of approximately 14 ft bls over the large Altura excavation area, and in a smaller area to an unknown depth (Figure 2). The soil was tested on site utilizing a field total petroleum hydrocarbon (TPH) analyzer using US Environmental Protection Agency (EPA) Method 418.1 modified (PSC & BBC, 1998). No information was available indicating the TPH cleanup level used. A total of 4,260 cubic yards (yd^3) of soil was excavated and transported to the Sundance Services, Inc. Parabo disposal facility located in Eunice, New Mexico (PSC & BBC, 1998). Based on reports provided by the defendants, no soil samples were submitted to a laboratory for analyses, and no soil analyses were included in their reports. A profile was likely required prior to acceptance of the waste soil at the Parabo disposal facility, but these data were not included in the references reviewed by HGC. No discussion was provided in the references regarding soil sampling at the base of the excavation for confirmation of complete excavation. As discussed in Section 4.6, field practices during this excavation represent non-compliance with NMOCD regulations.

2.3 Crude Oil Sludge Layer

Figure 3 shows Tasker Drive, south of Berry Drive, where a crude oil sludge layer was discovered in 1997 near lot 1329 (PSC & BBC, 1998). A crude oil sludge layer was also discovered by the resident at 1341 N. Cobb Drive sometime in November 1997 (PSC & BBC, 1998). As described below, these properties have been the focus of extensive investigative activities. Prior to the crude oil sludge layer discovery there are no records showing any site investigations performed by Shell. As discussed in Section 4.6, the lack of site closure activities in an area known to have unlined surface impoundments and/or petroleum releases constitutes a regulatory offense. Shell began investigations after the crude oil sludge layer near 1329 Tasker Drive was discovered, based on a request by the NMOCD (PSC & BBC, 1998).

During development of the house at lot 1329, the construction contractor observed an "asphalt-like" layer (Figure 2) that appeared to be crude oil spread on the ground, in accordance with normal past operating practices (PSC & BBC, 1998). The developer contacted the NMOCD who in turn contacted Shell. Shell representatives investigated the site in November 1997 and found that the top of the crude oil sludge layer was located approximately 1 to 2 ft bls and varied in thickness from several inches to several feet (PSC & BBC, 1998). Shell representatives sampled the crude oil sludge material in November 1997 and analyzed for TPH; benzene, toluene, ethylbenzene, and xylenes (BTEX); total chlorides, and toxicity characteristic leaching procedure (TCLP) metals. As mentioned above, no information regarding the sample locations or analytical results were provided.

The TPH analysis indicated the presence of n-alkanes C13 through C40 (PSC & BBC, 1998). The investigation of the crude oil sludge layer at lot 1341 N. Cobb Drive was performed in 1998 as discussed below in Section 2.4.3.

2.4 1998 Field Activities

In January of 1998, PSC representatives collected two soil samples from each of five soil borings. The 5 boreholes (SS-1 thru SS-5) were located on the four corners and the center of the area covered by 1329 and 1331 Tasker Drive (Figure 3). Sample locations were selected based on surface staining evident in the 1964 aerial photograph. Surface staining at this location is also evident in the 1949 aerial photograph (Figure 1). One sample was taken at a depth of 1 to 2 ft bls and one was taken beneath the crude oil sludge layer at a depth of 5 to 6 ft bls at each location. The samples were analyzed for volatile organic compounds (VOCs), semi-volatile organic compounds (SVOCs), pH, total dissolved solids (TDS), polychlorinated biphenols (PCBs), pesticides, inductively coupled plasma (ICP) metals, mercury, nitrates, cyanide, fluoride, and TPH using EPA Methods 8260, 8270, 8080, 8081a, 150.1, 160.1, 200.7, 245.1, 335.2, 340.2, 353.3, and 418.1, respectively (PSC & BBC, 1998).

The laboratory analytical results for organic compounds detected in soil samples collected during 1998 are provided in Table 2. Detected compounds for the January 1998 investigation at 1329 and 1331 Tasker Drive include tetrachloroethene (TCE) with a concentration of 0.54

milligrams per kilogram (mg/kg), ethylbenzene with detections ranging from 0.018 mg/kg to 2.0 mg/kg , and — and p-xylenes with detections ranging from 0.13 mg/kg to 39 mg/kg (Table 3). Detected metals of concern included arsenic with a concentration of 3.8 mg/kg, and cadmium with detections ranging from 0.06 mg/kg to 0.21 mg/kg (Table 2). TPH was detected in every sample with concentrations ranging from 1,800 mg/kg to 200,000 mg/kg (PSC & BBC, 1998). These concentrations were measured at depths between 1 and 6 feet, suggesting an increased risk to human health and the environment due to a negligible exposure pathway length. No sample methods or drilling procedures were described in the defendants' reports.

Between July 27 and October 17, 1998, PSC & BBC conducted extensive environmental activities in the area of the Westgate subdivision. These activities included:

1. a large scale soil gas survey (across the Westgate Subdivision, in the Grimes tank battery area, and in the Los Cuairo property),
2. soil sampling in 13 soil borings,
3. shallow soil sampling from 8 hand-augered boreholes, and
4. backhoe test pitting based on observed surface staining (PSC & BBC, 1998).

Each of these activities are described in the following sections. During the 34-year period prior to these activities while people resided within site boundaries, no other environmental investigations were conducted.

2.4.1 Large Scale Soil Gas Survey

An extensive soil gas survey was conducted by BBC in July and August 1998 using a direct push rig. TransGlobal Environmental Geosampling/Geochemistry conducted mobile laboratory analyses during this operation. Soil gas sampling locations were spaced on a 100-foot by 100-foot grid in areas of possible former oil operations (Figure 4). A total of 271 soil vapor samples were collected to depths of 5 ft bls. Samples were analyzed in the field for 14 volatile aromatic, and halogenated hydrocarbons by EPA Method 8021, as well as TPH, methane, ethane, propane, butane, pentane and hexane by EPA Method 8015 modified, respectively. The push probe was advanced to 5 ft bls, withdrawn ½ an inch, and 3 dead-space volumes were drawn through nylaflow tubing and discarded before a 20 cubic centimeter sample of gas was drawn into a glass airtight syringe and immediately transferred to the mobile laboratory for analysis.

Analytical data from the investigations are provided in Table 3, which is broken into three sections: 1) samples with TPH detections, 2) samples with detections other than TPH, and 3) samples with only methane detections. Of the 271 claimed soil vapor samples collected, measurable TPH was found in 62 samples with concentrations ranging from 1 to 3,000 milligrams per liter (mg/L). Samples contained concentrations of benzene ranging from 1 to 11 mg/L, ethylbenzene ranging from 1 to 55 mg/L, toluene ranging from 1 to 60 mg/L, and xylenes 1 to 300 mg/L (BTEX).

2.4.2 Soil Sampling

In August 1998, PSC and BBC drilled 13 boreholes (TSB-1 thru TSB-14) on two properties on 1329 and 1331 Tasker Drive to identify the horizontal and vertical extent of contamination (Figure 3). Locations were selected based on field observations and previous investigations. Soil samples were tested in the field using a photoionization detector (PID) and inspected for the presence of staining or odors. The sample locations adjacent to the residential foundation were sampled at a depth of 2 to 3 feet bls, 5 feet bls and 10 feet bls and submitted for laboratory analysis. Sampling at the other locations continued until no PID readings, staining, and odors were observed. Samples were collected from 2 to 3 ft bls, the 5-foot bls interval, the zone exhibiting the highest PID reading, and from the bottom of the borehole. No sample methods or drilling procedures were described in the defendants' reports.

All the samples, including those adjacent to house foundations, were analyzed for compounds listed in the New Mexico Water Quality Control Commission (WQCC) (NMAC 6.2 3-103 and 1-101). These compounds included VOCs, SVOCs, pH, TDS, PCBs, pesticides, ICP metals, mercury, nitrates, cyanide, fluoride, and TPH using EPA Methods 8260, 8270, 8080, 8081a, 150.1, 160.1, 200.7, 245.1, 335.2, 340.2, 353.3, and 418.1, respectively (PSC & BBC, 1998).

Table 2 shows that detected compounds included benzene with detections ranging from 0.1 to 0.71 mg/kg, ethylbenzene with detections ranging from 0.6 mg/kg to 17 mg/kg, naphthalene with concentrations ranging from 3.6 to of 8.02 mg/kg, m and p-xylenes with detections ranging from 0.063 mg/kg to 48 mg/kg, o-xylene with detections ranging from 0.089 mg/kg to 1.9 mg/kg, toluene with detections ranging from 0.0065 mg/kg to 1.0 mg/kg, 1-methylnaphthalene with detections ranging from 4.99 mg/kg to 43 mg/kg, 2-methylnaphthalene with detections ranging from 3.75 mg/kg to 39 mg/kg, di(2ethylhexyl)phthalate with a concentration of 0.38 mg/kg, anthracene with a concentration of 2.97 mg/kg, fluorene with detections ranging from 0.832 mg/kg to 1.8 mg/kg, phenanthrene with detections ranging from 1.94 to 3.3 mg/kg, and total phenols detections ranging from 0.07 mg/kg to 102 mg/kg. Detected metals of concern included arsenic with a detections ranging from 0.52 mg/kg to 7.3 mg/kg, cadmium with detections ranging from 0.11 mg/kg to 0.58 mg/kg, chromium with detections ranging from 1.9 mg/kg to 244 mg/kg, lead with detections ranging from 0.71 mg/kg to 92 mg/kg, and cyanide concentrations ranging from 0.01 to 0.07 mg/kg. TPH was detected with detections ranging from 11.53 mg/kg to 67,000 mg/kg. As discussed in Section 4.6, NMOCD regulations require steps leading to site closure, including site characterization and remediation, all of which were skipped prior to site redevelopment.

The Grimes tank battery 1998 investigation included 11 boreholes (GSB-1 thru GSB-11). These borings were drilled in the area that Altura Energy, Ltd. had excavated to determine contaminant concentrations in the base and sidewalls of the former pit. As discussed in Section 4.6, this delayed effort to determine adequate cleanup of the former pit was both unsuccessful and out of compliance with NMOCD regulations. Borings were also drilled around the former tank battery to horizontally and vertically delineate the extent of contamination from the Grimes tank battery.

One background sample was collected from a depth of 2 to 3 ft bls at sampling point GMW-2 (Figure 3). Locations were selected based on field observations and previous investigations and remedial efforts. Soil samples were tested in the field using a PID and inspected for the presence of staining or odors. Drilling and sampling continued until no PID readings, staining, and odors were observed. Samples that were collected from within the excavated zone were taken at depths between 2 to3 ft below the backfill material and at 5-foot intervals. Samples taken outside the excavated pit were sampled at 2 to 3 ft bls and at 5-foot intervals. No sample methods or drilling procedures were described in the defendants' reports.

The sample exhibiting the highest PID reading and the sample collected from the bottom of the borehole were submitted for laboratory analysis for TPH, BTEX and chlorides using EPA Methods 418.1, 8020 and 300. The samples collected from a depth of 2 to 3 ft bls and 2 to 3 ft below the fill material were analyzed for compounds listed in WQCC Sections 1-101 and 3-103 standards. These compounds included VOCs, SVOCs, pH, TDS, PCBs, pesticides, ICP metals, mercury, nitrates, cyanide, fluoride, and TPH using EPA Methods 8260, 8270, 8080, 8081a, 150.1, 160.1, 200.7, 245.1, 335.2, 340.2, 353.3, and 418.1, respectively (PSC & BBC, 1998).

Table 2 shows that detected compounds included ethylbenzene with detections ranging from 0.001 mg/kg to 4.27 mg/kg, total xylenes with detections ranging from 0.00008 mg/kg to 34.6 mg/kg, toluene with detections ranging from 0.4 mg/kg to 10.3 mg/kg, and total phenols detections ranging from 0.64 mg/kg to 21.2 mg/kg. Detected metals of concern included arsenic with detections ranging from 1.6 mg/kg to 5.3 mg/kg, cadmium with detections ranging from 0.1 mg/kg to 0.31 mg/kg, chromium with detections ranging from 2.3 mg/kg to 5.4 mg/kg, and lead with detections ranging from 0.72 mg/kg to 3.2 mg/kg. TPH detections ranged from 12 mg/kg to 6,380 mg/kg. Analytical results are provided in Table 2.

2.4.3 Shallow Soil Sampling

The residence at 1341 N. Cobb Drive was investigated between July 27 and October 7, 1998 using hand-augering to delineate the presence of contaminants. Hand-augering was performed rather than drilling due to access restrictions. Seven samples were taken from the back yard and one from the front yard (CSS-1 thru CSS-8) and were submitted to the laboratory for analysis (Figure 3) (PSC & BBC, 1998). All of the samples with the exception of the sample possessing the highest PID reading was analyzed for BTEX and TPH using EPA Methods 8020 and 418.1. The sample exhibiting the highest PID reading were analyzed for compounds listed in WQCC Sections 1-101 and 3-103 standards. These compounds included VOCs, SVOCs, pH, TDS, PCBs, pesticides, ICP metals, mercury, nitrates, cyanide, fluoride, and TPH using EPA Methods 8260, 8270, 8080, 8081a, 150.1, 160.1, 200.7, 245.1, 335.2, 340.2, 353.3, and 418.1, respectively (PSC & BBC, 1998).

Table 2 shows that detected compounds included — and p-xylene each with a concentration of 0.19 milligrams per kilogram (mg/kg) and total phenols with a concentration of 1.5 mg/kg. Table 2 also shows that detected metals of concern included cadmium with a concentration of 0.31 mg/kg, chromium with a concentration of 12 mg/kg, lead with a concentration of 7.2 mg/kg, and total mercury with a concentration of 0.32 mg/kg. TPH detections ranged from 19.2 mg/kg to 12,900 mg/kg. As discussed in Section 4.6 the presence of elevated TPH concentrations in soil at a residential property indicates Shell's failure to comply with NMOCD regulations prior to selling former oil production property.

2.4.4 Backhoe Test Pitting

An area immediately north of the Grimes tank battery was investigated between July 27 and October 7, 1998 where soil staining was observed (PSC & BBC, 1998). The horizontal and vertical extent of contamination was delineated by trenching with a backhoe. Trenching continued until no oil staining or odors were observed. No information was provided by the defendants regarding the location or size of the test trench. Reports provided by the defendants also failed to show any implementation of dust control or particulate matter air-monitoring during test trenching activities. The references also did not indicate if any soil samples were collected from the test trench or submitted to a laboratory for analyses. As discussed in Section 4.6, the lack of soil sampling prevents definition of contaminant boundaries in soil.

2.4.5 Groundwater Monitoring Well Installation

A total of thirteen groundwater monitoring wells were installed between August and October of 1998. Ten monitoring wells (GMW-1 thru GMW-10) were installed in the former Grimes Tank Battery area in order to identify the groundwater gradient at the site and the downgradient extent of groundwater impacts. Three groundwater monitoring wells (TMW-1 thru TMW-3) were installed at the Tasker Drive location to determine if groundwater was impacted. The groundwater monitoring wells were constructed with 4-inch Schedule 40 PVC well casing with 15-foot screens set 5 feet above and 10 feet below the groundwater table (PSC & BBC, 1998). Monitoring well locations are shown on Figure 5.

Soil samples during well construction were collected at 5-foot intervals, tested in the field for total VOCs using a PID, and inspected for the presence of staining or odors. No sample methods or drilling procedures were described in the defendants' reports. The sample exhibiting the highest PID reading and the sample collected from the zone in which groundwater was encountered were submitted for laboratory analysis. The samples were analyzed for compounds listed in the WQCC Sections 1-101 and 3-103 standards. These compounds included VOCs, SVOCs, pH, TDS, PCBs, pesticides, ICP metals, mercury, nitrates, cyanide, fluoride, and TPH using EPA Methods 8260, 8270, 8080, 8081a, 150.1, 160.1, 200.7, 245.1, 335.2, 340.2, 353.3, and 418.1, respectively (PSC & BBC, 1998). There were no groundwater samples taken during groundwater monitoring well installation in 1998.

Table 2 summarizes the 1998 soil detections. Detected compounds included benzene with detections ranging from 0.0012 mg/kg to 0.0021 mg/kg, ethylbenzene with detections ranging from 0.002 mg/kg to 3.1 mg/kg, naphthalene with detections ranging from 0.005 mg/kg to 0.023 mg/kg, total xylenes with detections ranging from 4.24 mg/kg to 15.8 mg/kg, toluene with detections ranging from 0.001 mg/kg to 0.092 mg/kg, 1-methylnaphthalene with detections ranging from 0.0097 mg/kg to 2.3 mg/kg, 2-methylnaphthalene with detections ranging from 0.01 mg/kg to 2.2 mg/kg, bis(2-ethylhexyl)phthalate with detections ranging from 0.020 mg/kg to 0.054 mg/kg, flourene with a concentration of 0.0012 mg/kg, phenanthrene with detections ranging from 0.0002 mg/kg to 0.024 mg/kg, and total phenols with detections ranging from 0.1 mg/kg to 23.4 mg/kg. Detected metals of concern included arsenic with detections ranging from 0.54 mg/kg to 3.6 mg/kg, cadmium with detections ranging from 0.12 mg/kg to 0.63 mg/kg, chromium with detections ranging from 0.07 mg/kg to 6.1 mg/kg, total mercury with a concentration of 0.0002 mg/kg and lead with detections ranging from 1.2 mg/kg to 2.4 mg/kg. TPH detections ranged from 0.533 mg/kg to 11,900 mg/kg. As discussed in Section 4.6, the presence of elevated levels of TPH in areas not characterized by surface staining, crude oil sludge layers, or other qualitatively identifiable crude oil contamination suggests the need for larger-scale site characterization including areas outside the 1998 soil gas survey.

2.5 Early 1999 Soil Borings

Between January and March 1999, BBC drilled two soil borings (GSB-16 and GSB-17) and one groundwater monitoring well (GMW-11) in the vicinity of 1341 N. Cobb Drive (Figure 3). Each borehole was drilled to a depth of 40 ft bls. No sample methods or drilling procedures were described in the defendants' reports. The samples taken from the 3- to 5-foot interval, and from the bottom of each borehole, and were submitted for analysis of VOCs, SVOCs, pH, TDS, PCBs, pesticides, ICP metals, mercury, nitrates, cyanide, fluoride, and TPH using EPA Methods 8260, 8270, 8080, 8081a, 150.1, 160.1, 200.7, 245.1, 335.2, 340.2, 353.3, and 418.1, respectively (BBC,1999).

Soil analytical results for samples collected during 1999 are provided in Table 4. The analytical results for the early 1999 soil borings near 1329 and 1331 Tasker Drive show that detected compounds included ethylbenzene with a concentration of 88 mg/kg, — and p-xylenes with a concentration of 390 mg/kg, o-xylene with a concentration of 105 mg/kg, and total phenols detections ranging from 0.679 mg/kg to 1.44 mg/kg. Detected metals of concern included arsenic with detections ranging from 1.0 mg/kg to 4.9 mg/kg, chromium with detections ranging from 2.9 mg/kg to 5.4 mg/kg, and lead with detections ranging from 2.0 mg/kg to 2.6 mg/kg. TPH was detected with concentration of 655 mg/kg.

The groundwater monitoring well (GMW-11) was constructed with 4-inch Schedule 40 PVC well casing with 15-foot screens set 5 feet above and 10 feet below the groundwater table (BBC, 1999). The location of this well is shown in Figure 5.

2.6 1999 South of 1329 Tasker Drive

Between January 25 and May 17, 1999, BBC drilled four soil borings (GSB-12 through GSB-15) located in each of the corner directions from GMW-9, which is located on the south of 1341 Cobb Drive. Borings were drilled to a minimum depth of 20 ft bls and sampled at intervals of 8 to 10 ft and at the bottom of the borehole (BBC, 1999). No sample methods or drilling procedures were described in the defendants' reports. Samples were analyzed for TPH, BTEX, and metals using EPA Methods 418.1, 8260 and 6010, respectively. No SVOC analyses were performed. As discussed in Section 4.3, the lack of SVOC analyses both demonstrates negligence of adequate site characterization and scientific inconsistency.

Table 4 shows that detected metals of concern included cadmium with detections ranging from 0.28 mg/kg to 0.42 mg/kg, chromium with detections ranging from 0.27 mg/kg to 0.49 mg/kg, and lead with detections ranging from 0.98 mg/kg to 4.24 mg/kg.

2.7 1999 East of Tasker Drive

Also Between January 25 and May 17, 1999, BBC drilled four soil borings (TSB-16 through TSB-19) and two groundwater monitoring wells (TMW-4 and TMW-5) (Figures 3 and 5) east of Tasker Drive. Each borehole was drilled to a minimum depth of 20 ft bls. Soil samples were taken from the interval showing the highest PID reading and from the bottom of each borehole and were submitted to the laboratory for analysis of VOCs, SVOCs, pH, TDS, PCBs, pesticides, ICP metals, mercury, nitrates, cyanide, fluoride, and TPH using EPA Methods 8260, 8270, 8080, 8081a, 150.1, 160.1, 200.7, 245.1, 335.2, 340.2, 353.3, and 418.1, respectively (BBC,1999).

Table 4 shows that detections included ethylbenzene with a concentration of 5.9 mg/kg, naphthalene with a concentration of 7 mg/kg, — and p-xylenes with a concentration of 20 mg/kg, 1-methylnaphthalene with a concentration of 17 mg/kg, 2-methylnaphthalene with a concentration of 19 mg/kg, phenanthrene with a concentration of 3.7 mg/kg, and total phenols with detections ranging from 0.609 mg/kg to 0.697 mg/kg. Detected metals of concern included arsenic with a concentration of 5.5 mg/kg, cadmium with detections ranging from 0.19 mg/kg to 0.43 mg/kg, chromium with detections ranging from 1.6 mg/kg to 3.7 mg/kg, total mercury with detections ranging from 0.10 mg/kg to 0.17 mg/kg, and lead with detections ranging from 0.52 mg/kg to 1.6 mg/kg. TPH was detected with detections ranging from 51.7 mg/kg to 17,200 mg/kg. As discussed in Section 4.6, the presence of elevated TPH concentrations in residential soil indicates non-compliance with NMOCD regulations.

The groundwater monitoring wells were constructed with 4-inch Schedule 40 PVC well casing with 15-foot screens set with 5 feet above and 10 feet below the groundwater table (BBC, 1999). The locations of these wells are shown in Figure 5. Groundwater samples were taken using unknown sampling methodologies sometime during or after well construction. General groundwater analytical data representative of multiple sampling events are presented in Table 5. Detections included benzene with concentrations ranging from 0.0087 to 0.031 micrograms per liter (µg/L), chrysene with a concentration of 0.006 µg/L, ethylbenzene with concentrations ranging from 0.0032 to 0.4 µg/L, — and p-xylenes with concentrations ranging from 0.00211 to 1.969 µg/L, o-xylene with concentrations ranging from 0.0024 to 0.458 µg/L, phenanthrene with concentrations ranging from 0.006 to 0.271 µg/L, and toluene with concentrations ranging from 0.0093 to 0.111 µg/L.

2.8 1999 North of Grimes Tank Battery

Soil containing contaminants north of the former Grimes battery was excavated and disposed of between January 25 and May 17, 1999 (Figure 2). The BBC report (1999) does not indicate depths or volumes of soil excavated. Three soil samples (GBN-1, GBN-2, and GBN-3) were grab sampled from unknown intervals and analyzed for VOCs, SVOCs, pH, TDS, PCBs, pesticides, ICP metals, mercury, nitrates, cyanide, fluoride, and TPH using EPA Methods 8260, 8270, 8080, 8081a, 150.1, 160.1, 200.7, 245.1, 335.2, 340.2, 353.3, and 418.1, respectively (BBC,1999). Soil was excavated using a front loader to determine the vertical and horizontal extent of contamination. Excavation continued until no visible hydrocarbons were apparent, and PID readings indicated no

VOCs. Following removal of contaminated soil, three additional samples (GBN-4, GBN-5, and GBN-6) were grab sampled in the same locations as the initial samples in the excavation to confirm that impacted soil had been completely excavated (BBC,1999). No sample methods or sampling procedures were described in the defendants' reports. Figure 3 shows the approximate locations of soil samples. Samples were submitted for analysis of total phenols, ICP metals, and TPH using EPA Methods 8270, 6010 and 418.1, respectively. SVOC analyses were requested during excavation, but not at the conclusion of excavation to verify SVOC cleanup. No VOC analyses were requested.

Table 4 shows that detections included total phenols with detections ranging from 1.66 mg/kg to 5.59 mg/kg. Detected metals of concern included arsenic with detections ranging from 1.3 mg/kg to 2.0 mg/kg, cadmium with detections ranging from 0.8 mg/kg to 1.5 mg/kg, chromium with detections ranging from 7.5 mg/kg to 10.0 mg/kg, total mercury with detections ranging from 0.11 mg/kg to 0.14 mg/kg, and lead with detections ranging from 4.5 mg/kg to 17.0 mg/kg. TPH detections ranged from 87.8 mg/kg to 52,000 mg/kg. As discussed in Section 4.6, the Grimes tank battery site should not have been considered decommissioned or closed in 1993 if elevated concentrations of TPH still existed in the vicinity of the battery.

2.9 1999 South of Grimes Tank Battery

Soil containing organic constituents south of the former Grimes battery was excavated and disposed of between January 25 and May 17, 1999 (Figure 2). Three additional soil samples (GBS-

1, GBS-2, and GBS-3) were taken at unknown intervals and analyzed for VOCs, SVOCs, pH, TDS, PCBs, pesticides, ICP metals, mercury, nitrates, cyanide, fluoride, and TPH using EPA Methods 8260, 8270, 8080, 8081a, 150.1, 160.1, 200.7, 245.1, 335.2, 340.2, 353.3, and 418.1, respectively (BBC,1999). Soil was excavated with a front loader to determine the vertical and horizontal extent of contamination. Excavation continued until no visible hydrocarbons were apparent, and odors or PID readings indicated no contamination. Following removal of contaminated soil, three additional samples (GBS-4, GBS-5, and GBS-6) were taken in the same locations as the initial samples to confirm that impacted soil had been excavated (BBC, 1999) (Figures 2 and 3). Samples were submitted for analysis of ICP metals, and TPH using EPA Methods 6010 and 418.1, respectively. A total of 3,306 yd^3 of near-surface contaminated soil was removed from areas north and south of the former Grimes tank battery (BBC, 1999). The information provided did not indicate the volume of soil excavated from each location. No sample methods or sampling procedures were described in the defendants' reports. SVOC analyses were requested during excavation of contaminated soil, but not at the conclusion of excavation during sampling of apparently clean soil to verify SVOC cleanup. No VOC analyses were requested.

Table 4 shows that detections in the excavated soil included arsenic with detections ranging from 1.6 mg/kg to 1.8 mg/kg, cadmium with detections ranging from 0.8 mg/kg to 1.5 mg/kg, chromium with detections ranging from 7.0 mg/kg to 14.0 mg/kg, and lead with detections ranging from 4.4 mg/kg to 12 mg/kg. TPH detections ranged from 419 mg/kg to 25,800 mg/kg. Again, the Grimes tank battery site should not have been considered decommissioned or closed in 1993 if elevated concentrations of TPH still existed in the vicinity of the battery.

2.10 May 1999 Soil Gas Survey

At the request of NMOCD, additional soil vapor sampling activities were performed at the site. BBC conducted an additional soil gas survey in May 1999. Sample locations included areas along Tasker Drive south of Barry Drive, and along Cobb Drive (Figures 3 and 4), at depths up to 11 ft bls, with an average depth for samples with detections of 5.7 feet.

Analytical results are provided in Table 6, which has been divided into two sections: 1) samples with TPH detections, and 2) samples with detections other than TPH. Samples were analyzed in the field for 14 volatile aromatic and halogenated hydrocarbons by EPA Method 8021, as well as TPH, methane, ethane, propane, butane, pentane and hexane by EPA Method 8015 modified, respectively (BBC, 1999). Of the 103 samples collected, 12 contained measurable TPH at concentrations up to 95 mg/L. There were 71 samples with VOCs other than TPH detected.

2.11 May 1999 Shallow Soil Sampling

At the request of NMOCD, additional soil sampling activities were performed at the site. BBC conducted 30 additional soil borings in May 1999 (TSB-20 through TSB-50). The shallow soil samples were collected from the backyards of the residences located at 1332 and 1328 Tasker Drive

(Figure 3). Soil samples were collected at a spacing of 5 feet to 10 feet and at a depth of 6 inches to 8 inches bls. The samples were tested in the field for VOCs with a PID and were visually inspected for the presence of staining and odors. Two samples, the sample exhibiting the highest PID reading and the sample possessing the highest degree of staining were submitted for analysis for TPH, aromatic volatile organics, halogenated volatile organics, poly-aromatic hydrocarbons, and metals using EPA Methods 8260, 8270 and 6010.

Table 4 shows that detections included acenaphthylene with a concentration of 109 mg/kg, benz(a)anthracene with a concentration of 7.5 mg/kg, benzo(a)pyrene with a concentration of 1.7 mg/kg, benzo(b)fluoranthene with a concentration of 27 mg/kg, benzo(k)fluoranthene with a concentration of 30 mg/kg, chrysene with a concentration of 147 mg/kg, fluorene with a concentration of 5 mg/kg, naphthalene with a concentration of 1.9 mg/kg, and phenanthrene with a concentration of 7.8 mg/kg. Detected metals of concern included arsenic with detections ranging from 1.2 mg/kg to 2.3 mg/kg, chromium with detections ranging from 3.8 mg/kg to 5.9 mg/kg, and lead with detections ranging from 1.5 mg/kg to 7.8 mg/kg. As discussed in Section 4.6, the presence of elevated TPH concentrations in a residential area indicates Shell's failure to comply with NMOCD regulations.

2.12 2000 and 2001 Grimes Well No. 8

A letter submitted by the NMOCD around May 2000 prompted additional investigative activities in the area of the abandoned Grimes Well No. 8. The well is located between 1507 and 1510 Cobb Drive (Figure 1). Investigative activities commenced in August 2000. Two soil samples were taken. Investigative reports did not include analytical data or sample locations and methodology. An additional investigation conducted in October 2000 included soil sampling at 1330 Tasker Drive and two additional locations west of the Grimes tank battery. No data regarding this sampling was provided. Based on the risk analysis, Shell recommended that no further action was necessary at the site (BBC, 2001). As discussed in Section 4.6, it is NMOCD's responsibility, not Shell's, to recommend no further action at a petroleum contaminated site. Similarly, no further action status could not have been obtained based on nonexistent analytical results.

In January 2001, additional investigative activities were conducted at 1422 Cobb Drive using a direct push sampling rig. Although sampling locations and analytical data were not provided, the report (BBC, 2001) states that soil samples were analyzed for TPH using EPA Method 418.1 and 8015 Modified diesel range organics/gasoline range organics (DRO/GRO), BTEX, GRO, DRO, and metals. BTEX and GRO results were nondetect in all samples. At the depth range of 0 to 3 ft bls, TPH and DRO results ranged from nondetected to 322 mg/kg for TPH using Method 418.1 and 88 mg/kg for DRO using Method 8015 Modified. In the depth range of 3 to 6 ft bls, Method 418.1 TPH results ranged from 2,460 mg/kg to 12,100 mg/kg. DRO results ranged from 55 mg/kg to 538 mg/kg using Method 8015 Modified. The report also stated that: "Analytical results for metals were consistent with prior sampling activities and results with the exception of barium, which had an elevated concentration" (BBC, 2001). A risk assessment was conducted in 2000 for the area near abandoned Shell Oil Company Well No. 8.

2.13 2002 Excavation

Based on a site visit in February 2003, HGC determined that an area spanning across 1331 and 1332 Tasker Drive and further west was excavated by BBC, with remedial activities concluding in December 2002 according to residents (Figure 2). Documentation recording remedial activities at this location has not been provided by the defendants at this time.

constitutes benzene mass (EPA and others, 1999).

Target soil remediation levels for contaminants of concern based on New Mexico Administrative Code Petroleum Storage Tank Regulations (NMAC 20.5.1) are summarized below:

Contaminant of Concern	Lowest Tier 1 Soil Target Level (mg/kg)	Detection Limit, Soil (mg/kg)
Benzene	0.02	0.025
Toluene	1.88	0.025
Ethylbenzene	36.9	0.025
Xylenes	2.59	0.025
1,2-Dibromoethane	0.0001	0.01
1,2-Dichloroethane	0.01	0.02
Methyl-tert-butyl-ether	0.08	0.13
Acenaphthene	2,570	50
Anthracene	16,900	50
Benz(a)anthracene	9.49	50
Benzo(a)pyrene	0.95	50
Benzo(b)fluoranthene	9.45	50
Benzo(k)fluoranthene	9.52	50
Chrysene	940	50
Dibenzo(a,h)anthracene	0.95	50
Fluoranthene	2,340	50
Fluorene	2,150	50
Total Napthalenes	2.24	50
Phenanthrene	1,590	50
Pyrene	1,760	50
Lead	53.08	5

Pristane (2,6,10,14-tetramethylpentadecane, C19) and phytane (2,6,10,14-tetramethylhexadecane, C20) are classified as medium to heavy aliphatic hydrocarbons and further characterized as isoprenoid alkanes in the n-alkane group. These compounds, based on their number of carbon atoms, are included in the light gas oil fraction of crude oil. Based on EPA and others (1999), West Texas Sour crude oil contains approximately 12% light gas oil by volume. In petroleum hydrocarbon contaminated soil, pristane and phytane are usually nearly equal in concentration (Tran, et. al., 1993). Pristane and phytane make up the largest fraction of aliphatic petroleum hydrocarbon compound group in oil sludge (Petrotech, 1999). Concentrations of pristane and phytane can range between 2 and 6 mg/g of oil in spill situations (Wang and others, 2000).

Metals are found at trace levels in some crude oil reserves. Concentrations of mercury in crude oil range from 100 parts per trillion to 20 parts per million, but more recent estimates place the average around 20 parts per billion (EPA and API, 2003). Cadmium has generally been characterized as a byproduct of machine operations associated with oil well drilling, pumping, and refining (PPS, 1996).

Documents referenced in this section are provided in Appendix D.

4. DISCUSSION

This section provides a critique of the information reviewed in the references provided, including the site setting, infrastructure, and the investigation activities described in the reports reviewed by HGC.

4.1 Hydrogeologic Setting

The geologic materials underlying the site consist of shallow surficial soils to depths of 5 to 8 feet, which are underlain by relatively impermeable limestones units extending to depth. This stratigraphic arrangement creates a barrier to downward vertical migration of hydrocarbons that may be spread on the ground or stored in pits, resulting in optimal conditions for evaporation. This, combined with the elevated summertime temperatures in the Hobbs have resulted in large evaporative losses of volatile constituents in the soil contamination. On calm days, or days with unfavorable light winds, ambient atmospheric concentrations of VOCs and possibly SVOCs were elevated in the southern one-half of Section 28.

4.2 Wells, Pipelines, and Storage Facilities

The Grimes No. 7 and No. 8 wells (Figure 1) were drilled in the 1940s and plugged and abandoned in 1953. The wells were plugged in accordance with NMOCD regulations at the time

(PSC & BBC, 1998).

Extensive land disturbance and soil staining are evident in 1949 aerial photography. The disturbance indicates that the oil production infrastructure in the southern one-half of Section 28 was also extensive. As in any industrial setting, there is a probability of product release with every piping connection made, every transfer or booster pumping station installed, and every valve replaced during normal industrial operations. In this rural setting, upset conditions typically resulted in a discharge of product to the land surface. In the four decades of oil production prior to the establishment of the EPA under the National Environmental Policy Act, oil production activities posed little environmental concern. However, after 1970, it became the responsibility of Shell to remediate all properties contaminated in the past under their ownership (40 Code of Federal Regulations 240-271).

The was no information provided in the references reviewed that described the operating practices at the Grimes tank battery. The nature of a storage facility is to accumulate product for the purposes of providing a relatively constant rate of delivery to a larger piping network. As such, at times when inflows to the storage facility exceed outflows, the excess is placed in shallow storage pits excavated in the shallow surficial soils. Pit volumes can be considerable, depending on the duration of the excess flows. Evaporation of VOCs and SVOCs from these crude oil ponds results in significant atmospheric loading of hydrocarbons and deposition of a less volatile sludge that remains after recovering usable product. The sludges were buried under a thin layer of soil leaving a minimal to negligible exposure pathway length, increasing the probability of impacts to humans and the environment.

4.2 Sampling Methodologies

For each of the investigations requiring an excavation, only disturbed soil samples were collected. When attempting to evaluate petroleum hydrocarbon contamination, undisturbed soil samples are preferred. Disturbed samples increase the chance of losing volatile constituents because the pore space is broken apart, exposing VOCs and SVOCs directly to the atmosphere. Disturbed samples can significantly underestimate contaminant concentrations in soil.

In addition, in many instances the visible appearance and odor of the soils at the base of an excavation were used to qualify a lack of impacted soils. This is not standard practice because appearance and odor are subjective and unreliable measures susceptible to personal bias and errors.

The lack of detailed descriptions of the sampling methodologies used casts uncertainty to the validity of the results because what little is known suggests that the VOC content of soil samples has been systematically underestimated.

4.3 Inconsistent Analyses

During the course of the environmental investigations associated with the site, there is an overwhelming lack of consistency in the analytes requested by the investigators from the analytical laboratory. The inconsistency spans not only from investigation to investigation, but from samples collected during and after a single investigation. For example, Sections 2.8 and 2.9 describe the Grimes tank battery excavation. SVOCs analyses were requested by the investigators for samples collected during each Grimes tank battery excavation, but not for samples collected after the excavation was completed. This practice prevents verification of the success of remedial efforts. Because crude oil is known to contain regulated SVOCs, this represents an important oversight that brings into question the completeness of the excavation with respect to removal of SVOCs. Similarly, between January 25 and May 17, 1999, BBC drilled four soil borings (GSB-12 through GSB-15) and requested no SVOCs analyses.

No soil samples were taken, no analyses were requested, and no results were reported for both the 1997 Altura Energy, Ltd excavations in the vicinity of the Grimes tank battery, and the backhoe test pitting conducted north of the Grimes tank battery between July 27 and October 7 1998.

4.4 Methane Detections

The presence of methane, ethane, and propane in many soil gas samples could be attributed to the improper completion of oil production wells and the slow bleed of these gases to the subsurface. However, in the May 1999 soil gas analytical results, the sum of carbon dioxide, nitrogen, and oxygen in these samples should be near 100%, and because of the relatively shallow depth of sample collection, the concentrations of these three fixed gases should reflect their relative abundance in the atmosphere. Many of the samples collected far from know oil production well completions with lower than atmospheric levels of oxygen have elevated carbon dioxide, suggesting active aerobic biodegradation of hydrocarbons. Because of the widespread nature of the methane detections, one could conclude that aerobic biodegradation of petroleum hydrocarbons is widespread, further suggesting that hydrocarbon contamination is widespread.

4.5 Undocumented Safety Precautions

During the trenching and excavation of the crude oil sludge layers prior to the 2002 excavation, there was no indication in the reports submitted by the defendants that dust control was performed or that breathing zone air was monitored. Defendants' reports indicate only that health and safety practices on site included standard Occupational Safety and Health Adminstration protocol (PSC & BBC, 1998; BBC, 1999). Air monitoring was limited to the use of a PID downwind from the remedial/investigative area. No other air monitoring procedures were used.

4.6 Out-of-Compliance Investigative and Remedial Procedures

The NMOCD enforces rules and regulations of the division and the Environmental Bureau of the NMOCD develops and enforces all of the environmental regulations and programs in the oil and gas industry for the prevention of groundwater contamination. The bureau uses an environmental permitting process that addresses all aspects of waste disposal. Appendix C provides NMOCD regulations on unlined surface impoundment closures and remediation of leaks, spills, and releases. According to these regulations, most recently published in 1993, the following summarizes the guidelines in place for closure of unlined surface impoundment closures and leaks, spills, and releases:

- At a minimum a closure plan should include locations of all pits or spills; procedures used to conduct soil and groundwater assessments; and procedures used to manage, remediate, and dispose of contaminated soil and groundwater.
- Site assessment should be performed prior to site closure either at the conclusion of remedial efforts or prior to the start of remedial efforts to determine the extent of contamination. Assessment should include the severity of the contamination and the potential environmental and public health threats using as risked-based ranking system (provided below).
- Soil samples should be taken a minimum of 3 feet below the bottom of the contaminated soil interval.
- Highly contaminated soils are those containing a free liquid hydrocarbon phase or those exhibiting gross hydrocarbon staining. Unsaturated contaminated soils are those containing measurable concentrations of BTEX and TPH. Contaminated soils must be excavated from the ground until a representative sample from the ground and walls of the excavation area shows contaminant levels below those outlined in the table below.

- Those areas within 1,000 feet of a water source and those within 200 feet of a domestic water source are assigned a risk value of 20, whereas those outside of those distance requirements are assigned a risk value of zero (see table below).
- All soil samples must be analyzed for TPH and BTEX.

Total Ranking Score			
Contaminant	**>19**	**10-19**	**0-9**
Benzene (ppm)	10	10	10
BTEX (ppm)	50	50	50
TPH (ppm)	100	1000	5000

Given the information above, field practices during soil excavations and Grimes tank battery decommissioning conducted by Altura Energy, Ltd. 1997 fail to comply with NMOCD regulations. No soil samples were taken, no were analyses run, and no results reported, therefore no confirmation of cleanup is possible. The defendants proceeded to backfilling these excavations prior to confirmation of cleanup. The defendants also failed to take soil samples during backhoe test pitting conducted between July 27 and October 7 1998. This constitutes a violation of NMOCD regulations in place to ensure characterization and adequate remediation of petroleum release areas. Similarly, the defendants failed to publically document the areas in which this 1998 excavation took place.

The presence of crude oil sludge layers at 1329 and 1331 Tasker Drive and 1341 N. Cobb Drive residences, both discovered in 1997, verifies the presence of either unlined crude oil surface impoundments and/or past petroleum releases not remediated according to NMOCD regulations. Each step in the site closure process seems to have been systematically overlooked by Shell for at least 5 years after which the current NMOCD regulations were published and for more than 5 years prior to the commencement of site assessment efforts.

The presence of elevated levels of TPH in areas not characterized by surface staining, crude oil sludge layers, or other qualitatively identifiable crude oil contamination suggests the need for larger-scale site characterization including areas outside the 1998 soil gas survey. Had the defendants followed NMOCD regulations, they would have characterized and assessed all areas with contaminant levels exceeding those outlined in the table above. Similarly, soil gas surveying does not meet the requirement of taking representative soil samples in all contaminated areas.

High TPH concentrations detected in the vicinity of residences include the following: 1) 17,200 mg/kg near 1328 and 1332 Tasker Drive between January 25 and May 17, 1999, and 2) 200,000 mg/kg near 1329 and 1331 Tasker Drive in January 1998. Similarly high TPH concentrations have been detected throughout the site. NMOCD has the right to require more stringent levels than those outlined above if warranted by site-specific conditions such as relative location of population centers, however, not even normal regulatory requirements have been met to date and the defendants have yet to complete an adequate assessment of site contamination. As discussed in Section 4.3, appropriate analyses of soil samples was not consistently performed to determine that contaminated areas had even been remediated to satisfy regulatory standards.

A risk analysis prompted by NMOCD was conducted by Shell in August 2000 in the vicinity of Grimes Well No. 8. The well is located between 1507 and 1510 Cobb Drive. No analytical results were publically documented but based on the risk analysis, Shell recommended that no further action was necessary at the site (BBC, 2001). This conclusion was apparently made by Shell, who was under a compliance order without the use of sampling and analysis procedures required by NMOCD.

5. CONCLUSIONS

Based on the documentation provided by the defendants, the site appears to be poorly characterized with respect to the extent of hydrocarbon contamination. Benzene, toluene, ethylbenzene, xylenes, TCE, SVOCs including poly-aromatic hydrocarbons, TPH, and mercury have been recently detected on site. Soil contaminant concentrations can be assumed to have been significantly higher in the past. In addition, no pristane or phytane analyses were ever conducted. The sampling and analysis methods employed at the site in all likelihood have greatly underestimated residual contamination. This fact combined with incomplete analytical suites for soil analyses, particularly the lack of SVOCs, make it difficult to fully assess the magnitude of historical health risks to local residents. Remedial efforts also in all likelihood have not adequately removed contaminants from the site. Based on the history of oil production in this area and the type of contamination either detected or known to exist in crude oil, it is likely that significant risks to public health do or have existed on site. Potential exposure pathways include volatilization from both shallow and deep soils, windblown dust from surface excavations, and direct surface contact or ingestion.

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TABLES

Table 1
Production Data - T18S, R38E, Southern One-Half of Section 28
(North Hobbs G/SA Unit)

Well No.	Earliest Production Record	Latest Production Record	Oil (BBLS)	Gas (MCF)	Water (BBLS)	Days Produced	Years Produced
131	1976	2000	193,266	335,529	1,984,276	7,760	21.3
132	1993	2002	184,351	107,757	1,229,598	3,507	9.6
141	<1972	2002	677,432	764,935	8,413,911	9,599	26.3
142	<1972	2002	133,462	558,131	2,314,166	14,523	39.8
231	<1972	1980	101,624	390,030	390,435	2,334	6.4
232	NA	NA	0	0	0	0	0.0
241	<1972	2002	563,290	765,801	6,293,243	9,662	26.5
242	NA	NA	0	0	0	0	0.0
243	<1972	2002	91,268	151,307	4,154,235	9,080	24.9
331	<1972	2002	284,617	450,333	3,219,159	9,524	26.1
341	<1972	2002	658,110	897,608	5,697,915	9,471	25.9
431	<1972	2002	1,036,998	1,400,765	2,963,275	9,384	25.7
441	<1972	1982	143,421	449,782	129,243	2,418	6.6
		Total =	4,067,839	6,271,978	36,789,456		
		Total Gallons^A =	170,849,238	NA	1,545,157,152		

Notes:

A = Assuming 42 gallons per barrel

NA = Not Applicable

MCF = millions of cubic feet

BBLS = Barrels

TABLE 2
1998 Soil Sample Detections
Hobbs, New Mexico

				E 150.1	E 160.1	E 300.0				E 418.1	E 901.1M	S 6010B																
Site Name	Sample Depth	Sample ID	Sample Date	pH	TDS	Chloride	Fluoride	Nitrate	Sulfate	TRPHC	Radium, Total	Aluminum	Arsenic	Barium	Boron	Cadmium	Chromium	Cobalt	Copper	Iron	Lead	Manganese	Mercury, Total	Molybdenum	Nickel	Selenium	Silver	Zinc
			Unit		mg/Kg	mg/Kg	mg/Kg	mg/Kg	mg/Kg	mg/Kg	pCi/gm	mg/Kg	mg/Kg	mg/Kg	mg/Kg	mg/Kg	mg/Kg	mg/Kg	mg/Kg	mg/Kg	mg/Kg	mg/Kg	mg/Kg	mg/Kg	mg/Kg	mg/Kg	mg/Kg	mg/Kg
Maximum of All Samples				**3820**	**10000**	**1900**	**17**	**10**	**920**	**200000**	**40.61**	**14000**	**7.3**	**970**	**26**	**0.64**	**244**	**11**	**13**	**12000**	**92**	**180**	**0.45**	**3.7**	**836**	**3.4**	**12**	**350**
Average of All Samples				**42.05**	**1123.46**	**129.08**	**3.94**	**2.68**	**160.87**	**10290.69**	**5.74**	**3853.96**	**2.39**	**165.24**	**11.07**	**0.26**	**7.05**	**4.97**	**3.02**	**2931.63**	**3.44**	**34.40**	**0.18**	**1.92**	**15.60**	**1.33**	**4.93**	**13.80**
Minimum of All Samples				**0**	**0**	**7.6**	**0.26**	**0.16**	**4.1**	**0.533**	**0**	**0.37**	**0.2**	**0.14**	**0.16**	**0.06**	**0.07**	**0.05**	**1**	**2.2**	**0.59**	**0.1**	**0.0002**	**1**	**0.79**	**0.52**	**0.87**	**0.16**
CSS-01		103639	7/28/98	NA	NA	NA	NA	NA	NA	460	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
CSS-02		103640	7/28/98	NA	NA	NA	NA	NA	NA	222	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
CSS-03		103641	7/28/98	NA	NA	NA	NA	NA	NA	39.8	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
CSS-04		103642	7/28/98	NA	NA	NA	NA	NA	NA	24.7	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
CSS-05		103643	7/28/98	NA	NA	NA	NA	NA	NA	19.2	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
CSS-06		103645	7/28/98	7.9	850	43	0.54	7.2	120	12900	1.67	13000	<0.5	95	20	0.31	12	11	5.4	11000	7.2	180	0.32	3.7	11	<0.5	<0.5	38
CSS-07		103644	7/28/98	NA	NA	NA	NA	NA	NA	55	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
CSS-08		104146	7/30/98	NA	NA	51	NA	NA	NA	<10	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
CSS Maxiumum				**7.9**	**850**	**51**	**0.54**	**7.2**	**120**	**12900**	**1.67**	**13000**	**ND**	**95**	**20**	**0.31**	**12**	**11**	**5.4**	**11000**	**7.2**	**180**	**0.32**	**3.7**	**11**	**ND**	**ND**	**38**
CSS Average				**7.9**	**850**	**47**	**0.54**	**7.2**	**120**	**1960.1**	**1.67**	**13000**	**ND**	**95**	**20**	**0.31**	**12**	**11**	**5.4**	**11000**	**7.2**	**180**	**0.32**	**3.7**	**11**	**ND**	**ND**	**38**
CSS Minimum				**7.9**	**850**	**43**	**0.54**	**7.2**	**120**	**19.2**	**1.67**	**13000**	**ND**	**95**	**20**	**0.31**	**12**	**11**	**5.4**	**11000**	**7.2**	**180**	**0.32**	**3.7**	**11**	**ND**	**ND**	**38**
GMW-01		109439	10/7/98	7.5	550	110	2	<1	100	16.9	5.27	3.1	<0.1	0.26	0.22	<0.01	<0.05	<0.05	<0.1	2.2	<0.05	0.38	<0.001	<0.1	<0.1	<0.05	<0.05	<0.1
GMW-02		109059	10/1/98	7.4	450	51	1.8	2.17	87	<0.5	3.42	39	<0.1	0.25	0.21	<0.01	0.07	0.05	<0.1	23	<0.05	0.28	0.0002	<0.1	<0.1	<0.05	<0.05	<0.1
GMW-03		109440	10/7/98	7.3	840	160	2.3	3.4	160	27	2.13	22	<0.1	0.61	0.42	<0.01	<0.05	0.05	<0.1	14	<0.05	0.25	<0.001	<0.1	<0.1	<0.05	<0.05	<0.1
GMW-04		109061	10/1/98	7.4	470	42	1.8	2.3	72	0.533	2.74	24	<0.1	0.31	0.16	<0.01	<0.05	<0.05	<0.1	14	<0.05	0.17	<0.0002	<0.1	<0.1	<0.05	<0.05	<0.1
GMW-05		109441	10/7/98	7.1	790	150	2	3.6	160	5	4.51	0.37	<0.1	0.25	<0.1	<0.01	<0.05	<0.05	<0.1	4.6	<0.05	0.19	<0.001	<0.1	<0.1	<0.05	<0.05	5.6
GMW-06		109063	10/1/98	7.4	500	46	1.7	4.81	79	<0.5	2.5	51	<0.1	0.41	0.23	<0.01	0.1	0.05	<0.1	34	<0.05	0.42	0.0002	<0.1	<0.1	<0.05	<0.05	0.16
GMW-07		109065	10/1/98	7.4	430	41	1.9	1.97	74	<0.5	2.27	11	<0.1	0.14	0.19	<0.01	<0.05	<0.05	<0.1	7.4	<0.05	<0.1	<0.0002	<0.1	<0.1	<0.05	<0.05	<0.1
GMW-08		109067	10/1/98	7.2	750	170	2	0.59	68	<0.5	2.62	6.6	<0.1	0.28	0.41	<0.01	<0.05	<0.05	<0.1	4.4	<0.05	0.18	<0.0002	<0.1	<0.1	<0.05	<0.05	<0.1
GMW-09		109069	10/1/98	7	540	57	2.1	2.39	85	7.28	3.43	10	<0.1	0.42	0.24	<0.01	<0.05	<0.05	<0.1	5.6	<0.05	0.16	<0.0002	<0.1	<0.1	<0.05	<0.05	<0.1
GMW-09	13-15'	106787	9/2/98	NA	NA	32	NA	NA	NA	2050	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
GMW-09	2-3'	106786	9/2/98	8.4	400	19	5.4	<0.4	110	24.1	11.01	4300	2.6	100	<10	0.17	3.8	5.3	2.3	3000	1.3	33	<0.1	1.7	5	<0.5	<0.5	5.8
GMW-09	50-52'	106788	9/2/98	NA	NA	96	NA	NA	NA	2310	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
GMW-09	63-65'	106458	8/31/98	8.9	150	25	1.2	1.7	7.2	206	5.84	1630	<0.5	15	<10	<0.1	2.4	2.5	<1	2000	1.2	19	<0.1	<1	2.2	<0.5	<0.5	4.6
GMW-09	8-10'	106457	8/31/98	8.1	880	16	9.9	1.7	140	11900	2.4	7100	<0.5	230	15	0.12	6.1	7.1	1.3	4300	2.4	37	<0.1	2.1	6.8	<0.5	<0.5	12
GMW-09D	63-65'	106459	8/31/98	8.7	252	21	1.3	<0.4	9.8	688	4.92	1900	0.59	19	<10	0.21	4	2.7	1	2300	1.2	23	<0.1	<1	2.4	<0.5	<0.5	5.1
GMW-10		109071	10/1/98	7.2	640	180	1.7	1.66	80	<0.5	4.22	12	<0.1	0.19	0.26	<0.01	<0.05	<0.05	<0.1	6.6	<0.05	<0.1	<0.0002	<0.1	<0.1	<0.05	<0.05	<0.1
GMW-10	2-3'	106789	9/2/98	8.2	1600	100	8.5	1.8	920	1960	2.98	5400	0.75	315	<10	0.13	5.3	5.4	2.7	4100	2.2	57	<0.1	1.2	4.9	<0.5	<0.5	9.9
GMW-10	3-5'	106342	8/27/98	7.9	900	27	9.5	8.6	180	4180	3.08	4000	<0.5	618	<10	0.5	3.4	5.9	1.6	2200	1.7	20	<0.1	1.6	6	<0.5	<0.5	6.8
GMW-10	3-5'	106790	9/2/98	NA	NA	150	NA	NA	NA	3960	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
GMW-10	50-52'	106791	9/2/98	NA	NA	54	NA	NA	NA	2920	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
GMW-10	63-65'	106343	8/27/98	8.7	470	20	1.2	1.8	73	<10	7.04	2300	<0.5	17	<10	0.42	3.6	2.7	2.1	2300	1.5	22	<0.1	1.3	2	<0.5	<0.5	6
GMW-10D	63-65'	106344	8/27/98	9	480	11	1.3	1.6	120	<10	11.55	2900	<0.5	11	<10	0.63	4.9	2.9	2.1	3500	1.6	25	<0.1	1.3	2.6	<0.5	<0.5	8.5
GMW Maxiumum				**9**	**1600**	**180**	**9.9**	**8.6**	**920**	**11900**	**11.55**	**7100**	**2.6**	**618**	**15**	**0.63**	**6.1**	**7.1**	**2.7**	**4300**	**2.4**	**57**	**0.0002**	**2.1**	**6.8**	**ND**	**ND**	**12**
GMW Average				**7.82**	**616.22**	**71.73**	**3.20**	**2.67**	**140.28**	**2016.99**	**4.55**	**1650.50**	**1.31**	**73.78**	**1.73**	**0.31**	**3.37**	**3.15**	**1.87**	**1323.10**	**1.64**	**14.88**	**0.00**	**1.53**	**3.99**	**ND**	**ND**	**6.45**
GMW Minimum				**7**	**150**	**11**	**1.2**	**0.59**	**7.2**	**0.533**	**2.13**	**0.37**	**0.59**	**0.14**	**0.16**	**0.12**	**0.07**	**0.05**	**1**	**2.2**	**1.2**	**0.16**	**0.0002**	**1.2**	**2**	**ND**	**ND**	**0.16**

				E 150.1	E 160.1	E 300.0				E 418.1	E 901.1M	S 6010B																
Site Name	Sample Depth	Sample ID	Sample Date	pH	TDS	Chloride	Fluoride	Nitrate	Sulfate	TRPHC	Radium, Total	Aluminum	Arsenic	Barium	Boron	Cadmium	Chromium	Cobalt	Copper	Iron	Lead	Manganese	Mercury, Total	Molybdenum	Nickel	Selenium	Silver	Zinc
			Unit		mg/Kg	mg/Kg	mg/Kg	mg/Kg	mg/Kg	mg/Kg	pCi/gm	mg/Kg	mg/Kg	mg/Kg	mg/Kg	mg/Kg	mg/Kg	mg/Kg	mg/Kg	mg/Kg	mg/Kg	mg/Kg	mg/Kg	mg/Kg	mg/Kg	mg/Kg	mg/Kg	mg/Kg
GSB-01	2-3'	105071	8/13/98	8.5	300	8.9	13	2.1	29	<10	4.8	6600	4.2	370	13	<0.1	4.9	8.1	1.9	4200	1.8	36	<0.25	2.8	8.6	0.85	<0.5	9.3
GSB-01	58-60'	105072	8/13/98	NA	NA	<8	NA	NA	NA	1770	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
GSB-01	63-65'	105073	8/13/98	NA	NA	13	NA	NA	NA	247	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
GSB-01B	63-65'	105074	8/13/98	NA	NA	11	NA	NA	NA	1340	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
GSB-02	45-47'	105225	8/14/98	NA	NA	26	NA	NA	NA	870	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
GSB-02	55-57'	105226	8/14/98	NA	NA	37	NA	NA	NA	1020	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
GSB-02	5-6'	105224	8/14/98	8.6	880	41	6.1	1.8	240	<10	1.67	3500	4.1	170	11	0.14	2.7	5.5	2.9	1900	0.72	28	<0.1	2.6	6.1	<0.5	<0.5	13
GSB-03	2-3'	107012	9/3/98	8.3	1100	87	5.9	<0.2	600	3130	21.2	4400	4.5	375	15	<0.1	3.8	3.1	3.1	2900	1.7	39	<0.1	2.2	6.9	0.86	<0.5	6.2
GSB-03	38-40'	107013	9/3/98	NA	NA	81	NA	NA	NA	1310	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
GSB-03	48-50'	107014	9/3/98	NA	NA	37	NA	NA	NA	771	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
GSB-03D	48-50'	107015	9/3/98	NA	NA	52	NA	NA	NA	1890	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
GSB-04	2-3'	107002	9/4/98	8	2700	1200	6	9.8	350	13.5	7.48	5900	2.9	166	15	0.16	5.4	7.6	2.5	4300	2.7	51	<0.1	2.6	7.9	<0.5	<0.5	11
GSB-04	48-50'	107003	9/4/98	NA	NA	40	NA	NA	NA	2900	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
GSB-04	57-59'	107004	9/4/98	NA	NA	66	NA	NA	NA	5340	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
GSB-04D	57-59'	107005	9/4/98	NA	NA	77	NA	NA	NA	5720	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
GSB-05	18-20'	106263	8/25/98	NA	NA	150	NA	NA	NA	<10	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
GSB-05	2-3'	106262	8/25/98	8.5	290	8.4	1.8	2.2	60	<10	0.96	2800	2.1	312	10	0.1	2.1	4.5	2.1	1500	0.78	11	<0.1	1.1	5.7	<0.5	<0.5	4.8
GSB-05	38-40'	106264	8/25/98	NA	NA	120	NA	NA	NA	<10	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
GSB-06	18-20'	106829	9/1/98	NA	NA	75	NA	NA	NA	<10	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
GSB-06	2-3'	106828	9/1/98	8.7	510	8.9	6.5	1.7	18	18.7	19.43	4940	1.6	730	16	0.22	6.3	8.7	2.6	3210	3.2	44	<0.1	2.6	11	1.6	0.94	12
GSB-06	38-40'	106830	9/1/98	NA	NA	11	NA	NA	NA	<10	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
GSB-07	2-3'	106259	8/25/98	8	1200	16	1.2	2.8	450	217	5.3	3800	<0.5	187	<10	0.31	3.1	6.3	2.1	2200	1.5	28	<0.1	1.3	5.3	<0.5	<0.5	44
GSB-07	33-35'	106260	8/25/98	NA	NA	37	NA	NA	NA	692	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
GSB-07	58-60'	106261	8/25/98	NA	NA	11	NA	NA	NA	<10	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
GSB-08	2-3'	107016	9/3/98	8.5	870	290	4.8	5.1	230	28	3.8	3000	5.3	276	10	<0.1	2.6	5.7	2.6	1800	1.2	30	<0.1	2.5	7.1	<0.5	<0.5	5
GSB-08	43-45'	107017	9/3/98	NA	NA	100	NA	NA	NA	1350	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
GSB-08	57-59'	107018	9/3/98	NA	NA	140	NA	NA	NA	4030	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
GSB-08D	57-59'	107019	9/3/98	NA	NA	140	NA	NA	NA	6380	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
GSB-11		107162	9/8/98	NA	NA	22	NA	NA	NA	704	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
GSB-11	2-3'	107159	9/8/98	8.2	380	160	7.2	<0.4	56	12	2.85	3900	3.9	274	10	<0.1	3.4	5.9	3.9	2600	1.7	24	<0.1	1.8	5.4	<0.5	<0.5	5.5
GSB-11	2-3'	107160	9/8/98	NA	NA	140	NA	NA	NA	1100	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
GSB-11	48-50'	107161	9/8/98	NA	NA	7.6	NA	NA	NA	1990	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
			GSB Maxiumum	**8.7**	**2700**	**1200**	**13**	**9.8**	**600**	**6380**	**21.2**	**6600**	**5.3**	**730**	**16**	**0.31**	**6.3**	**8.7**	**3.9**	**4300**	**3.2**	**51**	**ND**	**2.8**	**11**	**1.6**	**0.94**	**44**
			GSB Average	**8.37**	**914.44**	**103.67**	**5.83**	**3.64**	**225.89**	**1785.13**	**7.50**	**4315.56**	**3.58**	**317.78**	**12.50**	**0.19**	**3.81**	**6.16**	**2.63**	**2734.44**	**1.70**	**32.33**	**ND**	**2.17**	**7.11**	**1.10**	**0.94**	**12.31**
			GSB Minimum	**8**	**290**	**7.6**	**1.2**	**1.7**	**18**	**12**	**0.96**	**2800**	**1.6**	**166**	**10**	**0.1**	**2.1**	**3.1**	**1.9**	**1500**	**0.72**	**11**	**ND**	**1.1**	**5.3**	**0.85**	**0.94**	**4.8**
MW-02	13-15'	103766	7/29/98	8.3	2500	170	3.4	6.2	340	<10	13.32	2400	<0.5	65	<10	0.16	2.3	5	1.8	1800	1	25	<0.25	2.5	5.1	0.93	<0.5	11
MW-02	58-60'	103765	7/29/98	8.6	400	28	0.78	1.4	26	<10	40.61	2200	<0.5	7.4	<10	0.14	4.4	2.8	<1	2600	1.8	20	<0.25	1.1	2.7	<0.5	<0.5	11
MW-02D	62-64'	103764	7/29/98	8.7	570	35	0.84	1.5	36	10.6	11.48	2700	0.79	64	<10	0.15	5.4	3.4	1.3	3600	2.1	25	<0.25	1.7	3.3	<0.5	<0.5	11
MW-03	53-55'	104147	7/30/98	9.6	330	28	0.96	1.2	7.6	3000	4.8	2000	<0.5	20	<10	0.64	3.7	2.5	2.2	2400	2.7	18	<0.25	1.3	2.1	<0.5	<0.5	7
MW-03	63-65'	104148	7/30/98	3820	<10	37	1.1	<0.2	6.1	<10	4.34	2100	1.1	29	<10	0.61	4.4	2.9	2.3	2600	1.7	23	<0.25	1.9	2.6	0.76	<0.5	9.3
MW-04	18-20'	104099	8/1/98	8.7	160	85	2.9	2.4	85	<10	1.67	3800	3	100	<10	0.52	3.7	5	5.6	2300	1.9	40	<0.25	3	4.5	0.78	<0.5	7.3
MW-04	63-65'	104100	8/1/98	8.8	240	29	0.81	1.2	18	<10	13.32	2200	1.5	8.2	<10	0.58	3.7	2.7	1.6	2600	1.7	22	<0.25	1.6	2	<0.5	<0.5	5.2
MW-05	58-60'	104339	8/5/98	10.3	280	18	0.77	1.1	38	3170	4.33	<0.5	<0.5	<0.5	<10	<0.1	<0.5	<0.5	<1	<0.5	<0.5	<1	<0.5	<1	<0.5	<0.5	<0.5	<2
MW-05	63-65'	104340	8/5/98	8.9	260	37	0.83	<0.2	35	1950	4.33	<0.5	<0.5	<0.5	<10	<0.1	<0.5	<0.5	<1	<0.5	<0.5	<1	<0.5	<1	<0.5	<0.5	<0.5	<2
MW-06	3-5'	104532	8/6/98	8.7	3900	22	8.3	4.2	96	15.6	3.59	4940	1.8	320	12	0.32	5.4	6.2	2.1	3210	2	25	<0.1	1.6	8.6	<0.5	<0.5	20
MW-06	63-65'	104533	8/6/98	8.5	220	13	0.75	4.2	30	<10	2.38	1620	<0.5	9.7	<10	0.23	5.2	2.3	<1	1880	1.4	21	<0.1	<1	4.9	<0.5	<0.5	8.3
MW-07	48-50'	104633	8/10/98	8.8	200	10	0.79	1.2	8.8	<10	3.75	1950	0.68	6.5	<10	0.14	4.5	2.8	1.3	1790	2.2	21	<0.25	<0.5	2.4	<0.5	<0.5	3.7
MW-07	63-65'	104634	8/10/98	8.9	280	12	0.75	1.3	6	<10	6.55	1390	<0.5	4.3	<10	0.23	4	1.5	<1	1200	1.2	8.7	<0.25	<0.5	1.7	<0.5	<0.5	2.8
MW-08	28-30'	104948	8/12/98	8.7	530	85	2.9	1.3	92	<10	4.13	3100	0.2	490	<10	<0.1	3.2	4.3	1.9	2600	0.59	15	<0.1	2.4	4.3	1.2	<0.5	7.2
MW-08	63-65'	104949	8/12/98	9.1	170	18	1	1.2	4.9	<10	6.14	2700	<0.5	13	<10	<0.1	3.4	4.1	1.5	3200	<0.5	25	<0.1	1.6	4.2	<0.5	<0.5	6.3
MW-09D		109073	10/1/98	7.1	580	64	2.3	1.5	87	4.76	3.73	5	<0.1	0.43	0.23	<0.01	<0.05	<0.05	<0.1	3.2	<0.05	0.14	<0.0002	<0.1	<0.1	<0.05	<0.05	<0.1
			MW Maxiumum	**3820**	**3900**	**170**	**8.3**	**6.2**	**340**	**3170**	**40.61**	**4940**	**3**	**490**	**12**	**0.64**	**5.4**	**6.2**	**5.6**	**3600**	**2.7**	**40**	**ND**	**3**	**8.6**	**1.2**	**ND**	**20**
			MW Average	**246.98**	**708.00**	**43.19**	**1.82**	**2.14**	**57.28**	**1358.49**	**8.03**	**2364.64**	**1.30**	**81.25**	**6.12**	**0.34**	**4.10**	**3.50**	**2.16**	**2270.23**	**1.69**	**20.63**	**ND**	**1.87**	**3.72**	**0.92**	**ND**	**8.47**
			MW Minimum	**7.1**	**160**	**10**	**0.75**	**1.1**	**4.9**	**4.76**	**1.67**	**5**	**0.2**	**0.43**	**0.23**	**0.14**	**2.3**	**1.5**	**1.3**	**3.2**	**0.59**	**0.14**	**ND**	**1.1**	**1.7**	**0.76**	**ND**	**2.8**

				E 150.1	E 160.1	E 300.0				E 418.1	E 901.1M	S 6010B																
Site Name	Sample Depth	Sample ID	Sample Date	pH	TDS	Chloride	Fluoride	Nitrate	Sulfate	TRPHC	Radium, Total	Aluminum	Arsenic	Barium	Boron	Cadmium	Chromium	Cobalt	Copper	Iron	Lead	Manganese	Mercury, Total	Molybdenum	Nickel	Selenium	Silver	Zinc
			Unit		mg/Kg	mg/Kg	mg/Kg	mg/Kg	mg/Kg	mg/Kg	pCi/gm	mg/Kg	mg/Kg	mg/Kg	mg/Kg	mg/Kg	mg/Kg	mg/Kg	mg/Kg	mg/Kg	mg/Kg	mg/Kg	mg/Kg	mg/Kg	mg/Kg	mg/Kg	mg/Kg	mg/Kg
SS-1	2-3'	T89559	1/20/98	8.1	1600	340	0.26	NA	702	24800	NA	4900	<0.5	87	<10	<0.05	<10	<10	13	7300	<10	91	NA	<2	11	<1	<0.5	21
SS-1	5'	T89560	1/20/98	7.9	900	220	8	NA	240	14100	NA	4700	<0.5	320	<10	<0.05	<10	<10	<10	3300	<10	38	NA	<2	6.1	<1	<0.5	9.5
SS-2	2-3'	T89561	1/20/98	8.4	2600	300	0.77	NA	590	200000	NA	1900	<0.5	37	<10	<0.05	<10	<10	<10	1800	<10	47	NA	<2	7.6	<1	<0.5	6.7
SS-2	6'	T89562	1/20/98	9.2	2000	350	11	NA	82	30900	NA	4100	<0.5	650	<10	<0.05	<10	<10	<10	2400	<10	20	NA	<2	8.1	<1	<0.5	6.6
SS-3	2-3'	T89563	1/20/98	8.2	2000	120	0.85	NA	350	134000	NA	5800	<0.5	130	<10	<0.05	<10	<10	<10	5900	<10	93	NA	<2	8.9	<1	<0.5	17
SS-3	5.5'	T89564	1/20/98	8.1	2200	79	3.3	NA	310	21900	NA	5700	3.8	170	<10	<0.05	<10	<10	<10	4300	<10	51	NA	<2	6	1.8	<0.5	14
SS-4	1'	T89565	1/20/98	7.8	2400	39	0.92	NA	880	2930	NA	9200	<0.5	95	<10	0.06	<10	<10	<10	7600	<10	120	NA	<2	9	<1	<0.5	22
SS-4	5'	T89566	1/20/98	8.1	3000	59	7	NA	720	1800	NA	7500	<0.5	310	<10	0.21	<10	<10	<10	5500	<10	60	NA	<2	7.7	<1	<0.5	15
SS-5	2'	T89567	1/20/98	7.7	2800	99	0.66	NA	860	68200	NA	7800	<0.5	73	<10	0.06	<10	<10	<10	5800	<10	81	NA	<2	7.1	<1	<0.5	17
SS-5	5'	T89568	1/20/98	9.2	1700	260	11	NA	36	50200	NA	4200	<0.5	73	<10	<0.05	<10	<10	<10	2800	<10	19	NA	<2	6.1	<1	<0.5	6.9
SS Maxiumum				**9.2**	**3000**	**350**	**11**	**NA**	**880**	**200000**	**NA**	**9200**	**3.8**	**650**	**ND**	**0.21**	**ND**	**ND**	**13**	**7600**	**ND**	**120**	**NA**	**ND**	**11**	**1.8**	**ND**	**22**
SS Average				**8.27**	**2120.00**	**186.60**	**4.38**	**NA**	**477.00**	**54883.00**	**NA**	**5580.00**	**3.80**	**194.50**	**ND**	**0.11**	**ND**	**ND**	**13.00**	**4670.00**	**ND**	**62.00**	**NA**	**ND**	**7.76**	**1.80**	**ND**	**13.57**
SS Minimum				**7.7**	**900**	**39**	**0.26**	**NA**	**36**	**1800**	**NA**	**1900**	**3.8**	**37**	**ND**	**0.06**	**ND**	**ND**	**13**	**1800**	**ND**	**19**	**NA**	**ND**	**6**	**1.8**	**ND**	**6.6**
TMW-1		109052	10/1/98	7	830	250	1.7	0.16	58	<0.5	17.07	7	<0.1	0.19	0.37	<0.01	<0.05	<0.05	<0.1	5	<0.05	0.14	0.0017	<0.1	<0.1	<0.05	<0.05	<0.1
TMW-1	2-3'	105742	8/19/98	9.5	2700	94	2.1	1.5	34	28500	3.12	3800	0.68	150	<10	0.14	3.3	3.9	2.6	1970	1.1	34	<0.1	1.7	4.4	0.52	<0.5	11
TMW-1	63-65'	105743	8/19/98	8.7	170	82	0.84	2	9.1	18.1	11.3	1790	<0.5	5.5	<10	<0.1	3.5	<0.5	<1	1740	0.85	14	<0.1	<1	<0.5	1.3	<0.5	4.3
TMW-1A	63-65'	105744	8/19/98	8.7	510	240	1	1.9	13	63	11.3	2240	0.88	29	<10	0.13	4.1	1.1	1.1	2530	1.2	46	<0.1	<1	0.79	<0.5	<0.5	5.3
TMW-2		109054	10/1/98	7	880	230	1.5	0.41	51	<0.5	3.93	10	<0.1	0.26	0.44	<0.01	<0.05	<0.05	<0.1	5.9	<0.05	0.1	0.0006	<0.1	<0.1	<0.05	<0.05	<0.1
TMW-2	53-55'	105614	8/18/98	9	140	18	0.98	1.8	12	21.5	7.59	1900	<0.5	29	<10	<0.1	3.5	1.4	<1	2000	0.67	17	<0.1	<1	1.5	2.3	<0.5	6.1
TMW-2	63-65'	105615	8/18/98	8.4	130	27	0.99	1.8	12	50	0.74	2300	<0.5	34	<10	<0.1	3.7	1.8	<1	2300	1.3	21	<0.1	<1	1.5	<0.5	<0.5	5.3
TMW-3		109056	10/1/98	6.9	930	150	2.1	1.03	110	<0.5	6.23	15	<0.1	0.21	0.33	<0.01	<0.05	<0.05	<0.1	9	<0.05	0.16	0.0004	<0.1	<0.1	<0.05	<0.05	<0.1
TMW-3	2-3'	108238	9/22/98	8.2	460	81	3.4	<0.2	180	1460	7.54	3800	3.6	152	<10	<0.1	3.2	5	3.5	2500	1.4	25	0.28	1.2	6.4	<0.5	<0.5	7.5
TMW-3	23-25'	108240	9/22/98	8.6	200	42	2.4	<0.4	17	3574	1.91	1800	0.54	285	<10	0.14	2.6	3.7	2	1500	0.69	13	0.38	<1	3.9	<0.5	<0.5	4.2
TMW-3	3-5'	108239	9/22/98	8.4	470	41	7.4	<0.2	63	2986	14.14	5100	2	147	12	<0.1	4.2	5.5	1.3	3300	1.3	24	0.35	1.1	7	0.66	<0.5	8.4
TMW-3	63-65'	108241	9/22/98	9.2	170	31	1.5	<0.2	9	<10	10.6	2000	<0.5	10	<10	0.14	3.3	2.5	1.1	2400	1	20	0.45	<1	2.4	<0.5	<0.5	7.4
TMW Maxiumum				**9.5**	**2700**	**250**	**7.4**	**2**	**180**	**28500**	**17.07**	**5100**	**3.6**	**285**	**12**	**0.14**	**4.2**	**5.5**	**3.5**	**3300**	**1.4**	**46**	**0.45**	**1.7**	**7**	**2.3**	**ND**	**11**
TMW Average				**8.30**	**632.50**	**107.17**	**2.16**	**1.33**	**47.34**	**4584.08**	**7.96**	**2063.50**	**1.54**	**70.18**	**3.29**	**0.14**	**3.49**	**3.11**	**1.93**	**1688.33**	**1.06**	**17.87**	**0.21**	**1.33**	**3.49**	**1.20**	**ND**	**6.61**
TMW Minimum				**6.9**	**130**	**18**	**0.84**	**0.16**	**9**	**18.1**	**0.74**	**7**	**0.54**	**0.19**	**0.33**	**0.13**	**2.6**	**1.1**	**1.1**	**5**	**0.67**	**0.1**	**0.0004**	**1.1**	**0.79**	**0.52**	**ND**	**4.2**
TSB-01	2-3'	105955	8/20/98	8.1	6900	30	1.6	2.1	70	10200	8.4	10000	<0.5	90	17	0.32	8.6	7.8	5.4	7000	5.5	77	<0.1	2.9	8.6	0.57	<0.5	34
TSB-01	3-5'	105956	8/20/98	8.4	280	29	3.5	3.6	14	37100	3.29	6900	2.2	105	12	0.23	6	7.1	3.3	4800	3.9	64	<0.1	2	7.3	<0.5	<0.5	14
TSB-01	43-45'	105961	9/10/98	NA	NA	NA	NA	NA	NA	17.4	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
TSB-01	8-10'	105957	8/24/98	0	0	<2	<0.4	<0.4	<2	<10	2.95	<10	<0.5	<0.5	<10	<0.1	<0.5	<0.5	<1	<10	<0.5	<1	<0.1	<1	<0.5	<0.5	<0.5	<2
TSB-02	18-20'	105960	8/20/98	8.6	300	27	4.4	3.1	57	<10	5.81	7500	2.5	80	14	0.26	6.1	6.5	3.5	4900	18	65	<0.1	2	6.8	<0.5	<0.5	13
TSB-02	2-3'	105958	8/20/98	8.2	1400	26	4.6	2.3	29	12	12.03	10000	<0.5	82	17	0.35	9.2	8.3	5.4	8200	5.6	126	<0.1	2.5	8.3	<0.5	<0.5	21
TSB-02	3-5'	105959	8/20/98	8.2	1500	23	4.9	2.3	42	<10	30.66	10000	<0.5	93	17	0.33	9.2	8	5.3	8200	7.9	143	<0.1	2.4	8.4	<0.5	<0.5	23
TSB-03	18-20'	106198	8/20/98	8.7	540	180	4.1	2.1	110	<10	0	3300	1.4	286	<10	0.15	2.7	4	2.7	1900	<0.5	21	<0.1	1.5	3.4	<0.5	<0.5	5.1
TSB-03	2-3'	106196	8/20/98	7.7	630	200	1.4	7.6	150	<10	0	2200	<0.5	109	<10	0.23	1.9	3.5	2.1	1300	1.3	9.6	<0.1	<1	4.3	<0.5	<0.5	3.9
TSB-03	3-5'	106197	8/20/98	8.3	400	170	2.8	6.9	98	<10	0.99	5200	<0.5	315	12	0.14	4	5.2	3.9	2600	1.6	25	<0.1	3.7	8.2	<0.5	<0.5	6.6
TSB-04	18-20'	106093	8/20/98	8.5	500	38	5	2.1	180	<10	0	3000	5.3	340	<10	0.23	2.6	4.6	3.5	1700	2.3	26	<0.1	1.5	26	1.4	<0.5	5
TSB-04	18-20'	118969	8/20/98	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
TSB-04	2-3'	106091	8/20/98	8.2	620	120	8.4	2.5	140	<10	0	8700	3.5	470	16	0.13	6.7	8.1	2.9	5100	2.8	45	<0.1	2.2	8.3	1.3	<0.5	17
TSB-04	2-3'	118967	8/20/98	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
TSB-04	3-5'	106092	8/20/98	8.3	570	26	11	<0.4	140	11.53	0	14000	5.1	640	22	0.25	9.8	8.2	3.2	7500	5.5	41	<0.1	3.1	8.7	2.3	6.2	17
TSB-04	3-5'	118968	8/20/98	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
TSB-05	18-20'	106096	9/1/98	8.5	710	110	3.8	1.7	290	<10	0	2000	3.3	45	<10	0.18	2.2	4.1	5.3	1200	1.1	21	<0.1	1.7	4.1	0.6	<0.5	4.1
TSB-05	18-20'	118972	9/1/98	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
TSB-05	2-3'	106094	9/1/98	8.1	1400	360	2.8	1.7	330	<10	0	5700	7.3	184	10	0.3	4.8	5	2.9	3500	3.5	37	<0.1	1.7	5.8	3.4	<0.5	9

TABLE 2
1998 Soil Sample Detections
Hobbs, New Mexico

				E 150.1	E 160.1	E 300.0				E 418.1	E 901.1M	S 6010B																
Site Name	Sample Depth	Sample ID	Sample Date	pH	TDS	Chloride	Fluoride	Nitrate	Sulfate	TRPHC	Radium, Total	Aluminum	Arsenic	Barium	Boron	Cadmium	Chromium	Cobalt	Copper	Iron	Lead	Manganese	Mercury, Total	Molybdenum	Nickel	Selenium	Silver	Zinc
			Unit		mg/Kg	mg/Kg	mg/Kg	mg/Kg	mg/Kg	mg/Kg	pCi/gm	mg/Kg	mg/Kg	mg/Kg	mg/Kg	mg/Kg	mg/Kg	mg/Kg	mg/Kg	mg/Kg	mg/Kg	mg/Kg	mg/Kg	mg/Kg	mg/Kg	mg/Kg	mg/Kg	mg/Kg
TSB-05	2-3'	118970	9/1/98	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
TSB-05	3-5'	106095	9/1/98	8.2	1100	290	3.5	1.7	370	<10	0	6000	3.6	165	11	0.22	5.3	6.4	2.5	3600	2.8	37	<0.1	1.8	6.2	<0.5	<0.5	9.2
TSB-05	3-5'	118971	9/1/98	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
TSB-06	18-20'	106033	9/1/98	8.5	350	51	3.1	2.2	170	<10	1	1500	1.9	58	<10	0.39	2.2	4.2	3	1000	1.8	15	<0.1	1.5	<0.5	1.1	<0.5	3.5
TSB-06	18-20'	118877	9/1/98	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
TSB-06	2-3'	106034	9/1/98	8.4	420	34	5	1.8	82	86.8	3.01	4300	<0.5	970	26	0.52	244	11	5.9	12000	92	79	<0.1	2.9	<0.5	<0.5	<0.5	350
TSB-06	2-3'	118875	9/1/98	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
TSB-06	3-5'	106035	9/1/98	8.4	510	37	5.7	1.9	95	4490	3.09	4900	<0.5	242	11	0.36	4.4	6.1	1.8	3100	7.3	27	<0.1	1.8	<0.5	<0.5	<0.5	9.7
TSB-06	3-5'	118876	9/1/98	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
TSB-07	2-3'	106036	9/1/98	9.3	1000	320	1.1	2.3	140	20000	11.06	4200	2.2	194	15	0.3	3.7	6.2	1.7	2600	1.7	24	<0.1	1.6	6.5	<0.5	<0.5	6.4
TSB-07	2-3'	118880	9/1/98	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
TSB-07	2-3'	99A1348	9/1/98	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
TSB-07	28-30'	106028	8/27/98	NA	NA	NA	NA	NA	NA	<10	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
TSB-07	28-30'	118883	9/1/98	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
TSB-07	3-5'	106037	9/1/98	9.1	2100	760	8.5	<0.4	74	22900	1.01	3200	2	600	13	0.35	2.8	5.6	3.4	1600	1.8	16	<0.1	2.1	<0.5	<0.5	<0.5	4.5
TSB-07	3-5'	118881	9/1/98	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
TSB-07	8-10'	106038	9/1/98	8.9	1800	990	4.2	<0.4	18	139	3.76	6600	2	277	17	0.32	5.9	6.3	2.5	3900	2.4	28	<0.1	2.3	<0.5	<0.5	<0.5	8.3
TSB-07	8-10'	118882	9/1/98	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
TSB-08	2-3'	105408	9/1/98	9.5	4000	120	1.9	4.3	720	60300	4.33	2900	<0.5	240	<10	<0.1	2.5	4.5	1.2	1700	0.77	17	<0.1	1.3	4.5	<0.5	<0.5	5.5
TSB-08	2-3'	99A1349	9/1/98	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
TSB-08	3-5'	107006	9/1/98	9.4	10000	560	6.6	3.8	71	67000	8.48	6200	1.4	127	23	0.19	5.8	7.9	4.1	5300	4.1	69	<0.1	2.1	8	1.4	0.87	13
TSB-08	40-42'	107009	9/1/98	8.4	1000	550	1.5	1.7	62	15.6	19.93	2100	1.6	730	16	0.22	6.3	8.7	2.6	2500	3.2	44	<0.1	2.6	11	1.6	0.94	12
TSB-08	8-10'	107008	9/1/98	8.6	3200	1900	17	1.7	19	15.6	6.23	7700	<0.5	99	21	<0.1	7.3	8.2	2.1	6000	3.4	58	<0.1	2.2	8.8	<0.5	<0.5	14
TSB-08D	3-5'	107007	9/1/98	7.8	9600	660	8.1	6	180	21300	6.23	4900	2.3	160	16	<0.1	4.7	7	3.1	4000	2.7	59	<0.1	1.8	7.2	1.4	<0.5	11
TSB-09	18-20'	106099	9/1/98	8.4	850	260	3.8	<0.2	270	117	7.38	3300	3.8	146	<10	0.19	2.8	4	4.3	1800	1.8	23	<0.1	1.6	4.1	<0.5	<0.5	7.6
TSB-09	18-20'	120215	9/1/98	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
TSB-09	2-3'	106097	9/1/98	8.4	400	22	1	3.8	18	97.2	0.66	4900	1.6	230	12	0.15	4.2	6.4	4.4	2800	2.1	35	<0.1	1.8	6	<0.5	<0.5	9.6
TSB-09	2-3'	120213	9/1/98	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
TSB-09	3-5'	106098	9/1/98	8.5	440	18	11	1.8	170	<10	1.19	3600	1.4	161	<10	0.12	2.8	4.6	2.1	1800	1.8	15	<0.1	1.5	4.8	<0.5	<0.5	7.1
TSB-09	3-5'	120214	9/1/98	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
TSB-09	48-50'	120216	9/1/98	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
TSB-10	2-3'	106029	9/1/98	8.8	2100	70	1.4	1.9	420	18500	3.28	7700	1.5	125	19	0.53	8	7.7	8.4	7300	10	139	<0.1	2.8	16	<0.5	<0.5	68
TSB-10	2-3'	118884	9/1/98	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
TSB-10	28-30'	118887	9/1/98	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
TSB-10	3-5'	106030	9/1/98	9.4	3000	52	11	3.8	42	16000	4.75	5700	<0.5	127	13	0.37	4.8	6.1	1.8	3400	1.8	31	<0.1	2.2	<0.01	<0.5	<0.5	7.6
TSB-10	3-5'	118885	9/1/98	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
TSB-10	8-10'	118886	9/1/98	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
TSB-11	18-20'	106102	9/1/98	8.8	450	180	1.3	<0.2	12	22700	2.71	2400	2	87	<10	0.16	2.2	2.7	3.6	1500	1.2	14	<0.1	1	2.8	<0.5	<0.5	4.1
TSB-11	18-20'	118978	9/1/98	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
TSB-11	2-3'	106100	9/1/98	8.1	716	35	2	2	300	1210	6.56	5200	1.1	256	<10	0.14	3.8	6.4	3.6	2900	2	36	<0.1	1.5	7	0.89	<0.5	9.6
TSB-11	2-3'	118976	9/1/98	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
TSB-11	29-31'	106103	9/1/98	9.3	150	120	2.4	1.8	20	127	6.9	2400	1.4	30	<10	0.21	3.5	2.1	1.8	2400	1.7	1.8	<0.1	<1	2.3	2.9	<0.5	4.5
TSB-11	29-31'	118979	9/1/98	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
TSB-11	3-5'	106101	9/1/98	8.3	770	45	6.5	<0.4	180	1940	6.85	6600	<0.5	350	13	0.17	4.5	6.5	3.4	3300	1	23	<0.1	2.3	8.3	<0.5	<0.5	8
TSB-11	3-5'	118977	9/1/98	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
TSB-12	18-20'	106201	9/1/98	9	770	160	4.5	1.7	71	14700	2.51	3000	2.6	105	<10	0.17	2.4	4.8	4.3	1700	0.71	25	<0.1	1.3	4.5	<0.5	<0.5	5.2
TSB-12	2-3'	106199	9/1/98	8.1	890	33	4.7	10	460	1160	0.35	3900	<0.5	277	<10	0.16	<0.5	5.5	2.5	2000	0.92	21	<0.1	1.2	5.8	<0.5	<0.5	6.4
TSB-12	3-5'	106200	9/1/98	8.1	930	27	9	1.7	360	7800	0.5	4900	<0.5	328	10	0.25	4	6.2	2.6	2800	1.1	93	<0.1	1.6	836	<0.5	<0.5	13
TSB-12	48-50'	106202	9/1/98	8.8	270	56	1.1	<0.4	14	20.3	3.16	2100	<0.5	10	<10	0.12	3.8	2.9	1.7	2200	2.2	24	<0.1	<1	2	<0.5	<0.5	4.8
TSB-13	2-3'	106824	9/1/98	8.2	550	21	13	<0.4	150	10800	1.09	4800	<0.5	173	12	<0.1	4.1	6.1	1.1	3200	1.3	27	<0.1	1.5	6.3	<0.5	<0.5	7.4
TSB-13	23-25'	106827	9/1/98	8.7	1500	320	4	2.3	500	<10	1.11	4100	3	31	15	0.11	4	5.4	8.4	2500	2.4	27	<0.1	1.8	6	<0.5	<0.5	8.2
TSB-13	3-5'	106825	9/1/98	8.2	550	14	15	<0.4	150	15900	5.08	6900	<0.5	537	12	0.12	5.6	7.7	1.3	4700	2.4	48	<0.1	1.5	7	<0.5	<0.5	11
TSB-13	8-10'	106826	9/1/98	8.6	440	14	9	1.7	56	6250	8.19	4800	0.52	149	12	0.15	4.2	5.9	2.7	3200	0.97	28	<0.1	1.8	6.1	<0.5	<0.5	7.7
TSB-14	18-20'	104099b	8/1/98	8.7	160	85	2.9	2.4	85	<10	1.67	3800	3	100	<10	0.52	3.7	5	5.6	2300	1.9	40	<0.25	3	4.5	0.78	<0.5	7.3
TSB-14	40-42'	118283	8/1/98	9	120	18	1.3	<1	4.1	8240	1.23	1770	<0.5	29	<10	0.25	4	2.3	2.7	2510	0.76	20	<0.1	1.1	19	<0.5	12	5.6
TSB-14	63-65'	104100b	8/1/98	8.8	240	29	0.81	1.2	145.1	<10	13.32	2200	1.5	8.2	<10	0.58	3.7	2.7	1.6	2600	1.7	22	<0.25	1.6	2	<0.5	<0.5	5.2
TSB-14	63-65'	118284	8/1/98	8.6	120	24	1.3	<1	6.7	29	<1.54	1650	<0.5	8.3	<10	0.24	4.3	2.1	1.9	2200	0.81	17	<0.1	1	16	<0.5	8.6	6.1
TSB Maxiumum				**9.5**	**10000**	**1900**	**17**	**10**	**720**	**67000**	**30.66**	**14000**	**7.3**	**970**	**26**	**0.58**	**244**	**11**	**8.4**	**12000**	**92**	**143**	**ND**	**3.7**	**836**	**3.4**	**12**	**350**
TSB Average				**8.36**	**1409.49**	**200.30**	**5.03**	**2.90**	**154.02**	**11536.83**	**4.58**	**4972.17**	**2.54**	**216.71**	**15.14**	**0.25**	**9.98**	**5.77**	**3.33**	**3571.96**	**4.97**	**40.94**	**ND**	**1.94**	**28.19**	**1.51**	**5.72**	**18.13**
TSB Minimum				**0**	**0**	**14**	**0.81**	**1.2**	**4.1**	**11.53**	**0**	**1500**	**0.52**	**8.2**	**10**	**0.11**	**1.9**	**2.1**	**1.1**	**1000**	**0.71**	**1.8**	**ND**	**1**	**2**	**0.57**	**0.87**	**3.5**

NOTES:

NA = Sample not analyzed for this constituent.

ND = Constituent not detected at method detection limit.

TABLE 2
1998 Soil Sample Detections
Hobbs, New Mexico
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Site Name	Sample Depth	Sample ID	Sample Date	S 8021B	S 8080	S 8260B			S 8260B						S 8270								SM 4500 CN, CE	SM 5530 A,D
				Xylenes, Total	Solids, Percent	1,1-Dichloroethylene	Benzene	Ethylbenzene	m,p-xylene	Naphthalene	o-xylene	Tetrachloroethylene	Toluene	Trichloroethylene	1-Methylnaphthalene	2-Methylnaphthalene	Anthracene	Benzo(a)pyrene	bis(2-ethylhexyl)phthalate	Di(2-ethylhexyl)phthalate	Fluorene	Phenanthrene	Cyanide	Phenols, Total
			Unit	mg/Kg	mg/Kg	mg/Kg	mg/Kg	mg/Kg	mg/Kg	mg/Kg	mg/Kg	mg/Kg	mg/Kg	mg/Kg	mg/Kg	mg/Kg	mg/Kg	mg/Kg	mg/Kg	mg/Kg	mg/Kg	mg/Kg	mg/Kg	mg/Kg
			Maximum of All Samples	**34.6**	**97.8**	**0.37**	**0.71**	**17**	**48**	**8.02**	**1.9**	**0.54**	**10.3**	**0.42**	**43**	**39**	**2.97**	**8.81**	**0.054**	**0.38**	**1.8**	**3.3**	**0.08**	**310**
			Average of All Samples	**7.22**	**93.18**	**0.37**	**0.12**	**3.39**	**12.56**	**3.24**	**0.36**	**0.54**	**2.08**	**0.42**	**11.65**	**11.21**	**2.97**	**8.81**	**0.04**	**0.38**	**1.07**	**1.54**	**0.03**	**11.45**
			Minimum of All Samples	**0.000075**	**89.4**	**0.37**	**0.0012**	**0.000125**	**0.001**	**0.005**	**0.002**	**0.54**	**0.0065**	**0.42**	**0.003**	**0.01**	**2.97**	**8.81**	**0.02**	**0.38**	**0.0012**	**0.002**	**0.01**	**0.04**
CSS-01		103639	7/28/98	<0.00005	NA	NA	<0.05	<0.00005	NA	NA	NA	NA	<0.05	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
CSS-02		103640	7/28/98	<0.00005	NA	NA	<0.05	<0.00005	NA	NA	NA	NA	<0.05	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
CSS-03		103641	7/28/98	<0.00005	NA	NA	<0.05	<0.00005	NA	NA	NA	NA	<0.05	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
CSS-04		103642	7/28/98	<0.00005	NA	NA	<0.05	<0.00005	NA	NA	NA	NA	<0.05	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
CSS-05		103643	7/28/98	<0.00005	NA	NA	<0.05	<0.00005	NA	NA	NA	NA	<0.05	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
CSS-06		103645	7/28/98	NA	NA	<0.068	<0.068	<0.068	0.19	<50	<0.068	<0.068	<0.068	<0.068	<50	<50	<50	<50	NA	<50	<50	<50	<0.01	1.5
CSS-07		103644	7/28/98	<0.00005	NA	NA	<0.05	<0.00005	NA	NA	NA	NA	<0.05	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
CSS-08		104146	7/30/98	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
			CSS Maxiumum	**ND**	**NA**	**ND**	**ND**	**ND**	**0.19**	**ND**	**ND**	**ND**	**ND**	**ND**	**ND**	**ND**	**ND**	**ND**	**NA**	**ND**	**ND**	**ND**	**ND**	**1.5**
			CSS Average	**ND**	**NA**	**ND**	**ND**	**ND**	**0.19**	**ND**	**ND**	**ND**	**ND**	**ND**	**ND**	**ND**	**ND**	**ND**	**NA**	**ND**	**ND**	**ND**	**ND**	**1.5**
			CSS Minimum	**ND**	**NA**	**ND**	**ND**	**ND**	**0.19**	**ND**	**ND**	**ND**	**ND**	**ND**	**ND**	**ND**	**ND**	**ND**	**NA**	**ND**	**ND**	**ND**	**ND**	**1.5**
GMW-01		109439	10/7/98	NA	NA	<0.05	<0.05	0.2	0.72	0.005	0.17	<0.05	<0.05	<0.05	0.0097	0.01	<0.001	<0.001	0.035	NA	0.0012	0.002	<0.01	<0.01
GMW-02		109059	10/1/98	NA	NA	<0.001	<0.001	<0.001	0.002	<0.001	<0.001	<0.001	0.001	<0.001	<0.001	<0.001	<0.001	<0.001	NA	<0.001	<0.001	<0.001	<0.01	0.1
GMW-03		109440	10/7/98	NA	NA	<0.1	<0.1	<0.1	0.58	0.023	0.12	<0.1	<0.1	<0.1	0.034	0.024	<0.001	<0.001	0.02	NA	<0.001	<0.001	<0.01	<0.01
GMW-04		109061	10/1/98	NA	NA	<0.001	0.002	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	NA	<0.001	<0.001	<0.001	<0.01	0.7
GMW-05		109441	10/7/98	NA	NA	<0.1	<0.1	0.19	1.22	0.01	0.275	<0.1	<0.1	<0.1	0.15	0.16	<0.001	<0.001	0.054	NA	<0.001	0.024	<0.01	<0.01
GMW-06		109063	10/1/98	NA	NA	<0.001	<0.001	0.002	0.007	<0.001	0.002	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	NA	<0.001	<0.001	<0.001	<0.01	0.1
GMW-07		109065	10/1/98	NA	NA	<0.001	0.0012	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	NA	<0.001	<0.001	<0.001	<0.01	<0.01
GMW-08		109067	10/1/98	NA	NA	<0.001	0.0021	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	NA	<0.001	<0.001	<0.001	<0.01	<0.01
GMW-09		109069	10/1/98	NA	NA	<0.001	0.0018	0.018	0.08	<0.001	0.027	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	NA	<0.001	<0.001	<0.001	<0.01	<0.01
GMW-09	13-15'	106787	9/2/98	6.48	NA	NA	<0.05	0.93	NA	NA	NA	NA	<0.05	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
GMW-09	2-3'	106786	9/2/98	NA	NA	<0.036	<0.036	<0.036	<0.036	<0.25	<0.036	<0.036	<0.036	<0.036	<0.25	<0.25	<0.25	<0.25	NA	<0.25	<0.25	<0.25	<0.01	1.2
GMW-09	50-52'	106788	9/2/98	4.24	NA	NA	<0.05	0.546	NA	NA	NA	NA	<0.05	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
GMW-09	63-65'	106458	8/31/98	NA	NA	<0.025	<0.025	<0.025	<0.025	<0.25	<0.025	<0.025	<0.025	<0.025	<0.25	<0.25	<0.25	<0.25	NA	<0.25	<0.25	<0.25	<0.01	3.8
GMW-09	8-10'	106457	8/31/98	NA	NA	<0.025	<0.025	<0.025	<0.025	<1.25	<0.025	<0.025	<0.025	<0.025	<1.25	<1.25	<1.25	<1.25	NA	<1.25	<1.25	<1.25	<0.01	14.47
GMW-09D	63-65'	106459	8/31/98	NA	NA	<0.025	<0.025	<0.025	<0.025	<0.25	<0.025	<0.025	<0.025	<0.025	<0.25	<0.25	<0.25	<0.25	NA	<0.25	<0.25	<0.25	<0.01	1.8
GMW-10		109071	10/1/98	NA	NA	<0.001	0.0016	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	NA	<0.001	<0.001	<0.001	<0.01	<0.01
GMW-10	2-3'	106789	9/2/98	NA	NA	<0.094	<0.094	3.1	15	<0.25	<0.094	<0.094	<0.094	<0.094	2.3	2.2	<0.25	<0.25	NA	<0.25	<0.25	<0.25	<0.01	1.8
GMW-10	3-5'	106342	8/27/98	NA	NA	<0.025	<0.025	<0.025	<0.025	<12.5	<0.025	<0.025	<0.025	<0.025	<12.5	<12.5	<12.5	<12.5	NA	<12.5	<12.5	<12.5	<0.01	5.1
GMW-10	3-5'	106790	9/2/98	15.8	NA	NA	<0.05	2.48	NA	NA	NA	NA	<0.05	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
GMW-10	50-52'	106791	9/2/98	4.31	NA	NA	<0.05	0.577	NA	NA	NA	NA	0.092	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
GMW-10	63-65'	106343	8/27/98	NA	NA	<0.025	<0.025	<0.025	<0.025	<0.25	<0.025	<0.025	<0.025	<0.025	<0.25	<0.25	<0.25	<0.25	NA	<0.25	<0.25	<0.25	<0.01	23.4
GMW-10D	63-65'	106344	8/27/98	NA	NA	<0.025	<0.025	<0.025	<0.025	<0.25	<0.025	<0.025	<0.025	<0.025	<0.25	<0.25	<0.25	<0.25	NA	<0.25	<0.25	<0.25	<0.01	6.9
			GMW Maxiumum	**15.8**	**NA**	**ND**	**0.0021**	**3.1**	**15**	**0.023**	**0.275**	**ND**	**0.092**	**ND**	**2.3**	**2.2**	**ND**	**ND**	**0.054**	**ND**	**0.0012**	**0.024**	**ND**	**23.4**
			GMW Average	**7.71**	**NA**	**ND**	**0.00**	**0.89**	**2.52**	**0.01**	**0.12**	**ND**	**0.09**	**ND**	**0.62**	**0.60**	**ND**	**ND**	**0.04**	**ND**	**0.00**	**0.01**	**ND**	**5.40**
			GMW Minimum	**4.24**	**NA**	**ND**	**0.0012**	**0.002**	**0.002**	**0.005**	**0.002**	**ND**	**0.092**	**ND**	**0.0097**	**0.01**	**ND**	**ND**	**0.02**	**ND**	**0.0012**	**0.002**	**ND**	**0.1**

				S 8021B	S 8080	S 8260B			S 8260B						S 8270									SM 4500 CN, CE	SM 5530 A,D
Site Name	Sample Depth	Sample ID	Sample Date	Xylenes, Total	Solids, Percent	1,1-Dichloroethylene	Benzene	Ethylbenzene	m,p-xylene	Naphthalene	o-xylene	Tetrachloroethylene	Toluene	Trichloroethylene	1-Methylnaphthalene	2-Methylnaphthalene	Anthracene	Benzo(a)pyrene	bis(2-ethylhexyl)phthalate	Di(2-ethylhexyl)phthalate	Fluorene	Phenanthrene	Cyanide	Phenols, Total
			Unit	mg/Kg	mg/Kg	mg/Kg	mg/Kg	mg/Kg	mg/Kg	mg/Kg	mg/Kg	mg/Kg	mg/Kg	mg/Kg	mg/Kg	mg/Kg	mg/Kg	mg/Kg	mg/Kg	mg/Kg	mg/Kg	mg/Kg	mg/Kg	mg/Kg
GSB-01	2-3'	105071	8/13/98	NA	NA	<0.025	<0.025	<0.025	<0.025	<0.25	<0.025	<0.025	<0.025	<0.025	<0.25	<0.25	<0.25	<0.25	NA	<0.25	<0.25	<0.25	0.062	<0.25
GSB-01	58-60'	105072	8/13/98	0.000857	NA	NA	<0.05	<0.00005	NA	NA	NA	NA	<0.05	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
GSB-01	63-65'	105073	8/13/98	0.000075	NA	NA	<0.05	<0.00005	NA	NA	NA	NA	<0.05	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
GSB-01B	63-65'	105074	8/13/98	<0.00005	NA	NA	<0.05	<0.00005	NA	NA	NA	NA	<0.05	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
GSB-02	45-47'	105225	8/14/98	0.00125	NA	NA	<0.05	0.000125	NA	NA	NA	NA	0.101	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
GSB-02	55-57'	105226	8/14/98	0.00262	NA	NA	<0.05	0.000296	NA	NA	NA	NA	0.481	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
GSB-02	5-6'	105224	8/14/98	NA	NA	<0.025	<0.025	<0.025	<0.025	<0.25	<0.025	<0.025	<0.025	<0.025	<0.25	<0.25	<0.25	<0.25	NA	<0.25	<0.25	<0.25	0.01	<0.01
GSB-03	2-3'	107012	9/3/98	NA	NA	<0.03	<0.03	<0.03	<0.03	<0.25	<0.03	<0.03	<0.03	<0.03	<0.25	<0.25	<0.25	<0.25	NA	<0.25	<0.25	<0.25	<0.01	4
GSB-03	38-40'	107013	9/3/98	2.5	NA	NA	<0.05	0.321	NA	NA	NA	NA	<0.05	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
GSB-03	48-50'	107014	9/3/98	8	NA	NA	<0.05	1.1	NA	NA	NA	NA	<0.05	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
GSB-03D	48-50'	107015	9/3/98	18.4	NA	NA	<0.05	2.8	NA	NA	NA	NA	2.07	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
GSB-04	2-3'	107002	9/4/98	NA	NA	<0.056	<0.056	<0.056	<0.056	<0.25	<0.056	<0.056	<0.056	<0.056	<0.25	<0.25	<0.25	<0.25	NA	<0.25	<0.25	<0.25	<0.01	1.8
GSB-04	48-50'	107003	9/4/98	21.3	NA	NA	<0.1	3.21	NA	NA	NA	NA	0.4	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
GSB-04	57-59'	107004	9/4/98	6.13	NA	NA	<0.1	1.79	NA	NA	NA	NA	5.54	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
GSB-04D	57-59'	107005	9/4/98	9.56	NA	NA	<0.1	2.17	NA	NA	NA	NA	10.3	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
GSB-05	18-20'	106263	8/25/98	<0.05	NA	NA	<0.05	<0.05	NA	NA	NA	NA	<0.05	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
GSB-05	2-3'	106262	8/25/98	NA	NA	<0.025	<0.025	<0.025	<0.025	<2.5	<0.025	<0.025	<0.025	<0.025	<2.5	<2.5	<2.5	<2.5	NA	<2.5	<2.5	<2.5	<0.01	21.2
GSB-05	38-40'	106264	8/25/98	<0.05	NA	NA	<0.05	<0.05	NA	NA	NA	NA	<0.05	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
GSB-06	18-20'	106829	9/1/98	0.162	NA	NA	<0.05	<0.05	NA	NA	NA	NA	<0.05	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
GSB-06	2-3'	106828	9/1/98	NA	NA	<0.083	<0.083	<0.083	<0.083	<0.25	<0.083	<0.083	<0.083	<0.083	<0.25	<0.25	<0.25	<0.25	NA	<0.25	<0.25	<0.25	<0.01	0.64
GSB-06	38-40'	106830	9/1/98	<0.05	NA	NA	<0.05	<0.05	NA	NA	NA	NA	<0.05	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
GSB-07	2-3'	106259	8/25/98	NA	NA	<0.025	<0.025	<0.025	<0.025	<0.25	<0.025	<0.025	<0.025	<0.025	<0.25	<0.25	<0.25	<0.25	NA	<0.25	<0.25	<0.25	<0.01	2.9
GSB-07	33-35'	106260	8/25/98	2.42	NA	NA	<0.05	0.433	NA	NA	NA	NA	<0.05	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
GSB-07	58-60'	106261	8/25/98	<0.05	NA	NA	<0.05	<0.05	NA	NA	NA	NA	<0.05	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
GSB-08	2-3'	107016	9/3/98	NA	NA	<0.087	<0.087	<0.087	<0.087	<0.25	<0.087	<0.087	<0.087	<0.087	<0.25	<0.25	<0.25	<0.25	NA	<0.25	<0.25	<0.25	<0.01	1.9
GSB-08	43-45'	107017	9/3/98	4.04	NA	NA	<0.05	0.558	NA	NA	NA	NA	<0.05	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
GSB-08	57-59'	107018	9/3/98	7.2	NA	NA	<0.05	1.78	NA	NA	NA	NA	5.69	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
GSB-08D	57-59'	107019	9/3/98	34.6	NA	NA	<0.05	4.27	NA	NA	NA	NA	2.81	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
GSB-11		107162	9/8/98	3.25	NA	NA	<0.05	0.309	NA	NA	NA	NA	<0.05	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
GSB-11	2-3'	107159	9/8/98	NA	NA	<0.091	<0.091	<0.091	<0.091	<0.25	<0.091	<0.091	<0.091	<0.091	<0.25	<0.25	<0.25	<0.25	NA	<0.25	<0.25	<0.25	<0.01	2.8
GSB-11	2-3'	107160	9/8/98	2.95	NA	NA	<0.05	0.469	NA	NA	NA	NA	<0.05	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
GSB-11	48-50'	107161	9/8/98	7.41	NA	NA	<0.05	0.694	NA	NA	NA	NA	<0.05	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
GSB Maxiumum				**34.6**	**NA**	**ND**	**ND**	**4.27**	**ND**	**ND**	**ND**	**ND**	**10.3**	**ND**	**ND**	**ND**	**ND**	**ND**	**NA**	**ND**	**ND**	**ND**	**0.062**	**21.2**
GSB Average				**7.11**	**NA**	**ND**	**ND**	**1.33**	**ND**	**ND**	**ND**	**ND**	**3.42**	**ND**	**ND**	**ND**	**ND**	**ND**	**NA**	**ND**	**ND**	**ND**	**0.04**	**5.03**
GSB Minimum				**0.000075**	**NA**	**ND**	**ND**	**0.000125**	**ND**	**ND**	**ND**	**ND**	**0.101**	**ND**	**ND**	**ND**	**ND**	**ND**	**NA**	**ND**	**ND**	**ND**	**0.01**	**0.64**
MW-02	13-15'	103766	7/29/98	NA	NA	<0.025	<0.025	<0.025	<0.025	<0.25	<0.025	<0.025	<0.025	<0.025	<0.25	<0.25	<0.25	<0.25	NA	<0.25	<0.25	<0.25	0.08	0.25
MW-02	58-60'	103765	7/29/98	NA	NA	<0.025	<0.025	<0.025	<0.025	<0.25	<0.025	<0.025	<0.025	<0.025	<0.25	<0.25	<0.25	<0.25	NA	<0.25	<0.25	<0.25	<0.01	11
MW-02D	62-64'	103764	7/29/98	NA	NA	<0.025	<0.025	<0.025	<0.025	<0.25	<0.025	<0.025	<0.025	<0.025	<0.25	<0.25	<0.25	<0.25	NA	<0.25	<0.25	<0.25	0.02	3.8
MW-03	53-55'	104147	7/30/98	NA	NA	<0.5	<0.5	2	8.7	<1.25	1.4	<0.5	<0.5	<0.5	2.9	2.85	<1.25	<1.25	NA	<1.25	<1.25	<1.25	<0.01	9.5
MW-03	63-65'	104148	7/30/98	NA	NA	<0.1	<0.1	0.15	0.81	<1.25	0.18	<0.1	<0.1	<0.1	2.6	2.52	<1.25	<1.25	NA	<1.25	<1.25	<1.25	0.02	310
MW-04	18-20'	104099	8/1/98	NA	NA	<0.025	<0.025	<0.025	<0.025	<0.25	<0.025	<0.025	<0.025	<0.025	<0.25	<0.25	<0.25	<0.25	NA	<0.25	<0.25	<0.25	0.01	6.5
MW-04	63-65'	104100	8/1/98	NA	NA	<0.025	<0.025	<0.025	<0.025	<0.25	<0.025	<0.025	<0.025	<0.025	<0.25	<0.25	<0.25	<0.25	NA	<0.25	<0.25	<0.25	0.07	2.75
MW-05	58-60'	104339	8/5/98	NA	NA	<0.025	<0.025	<0.025	<0.025	<2.5	<0.025	<0.025	<0.025	<0.025	<2.5	<2.5	<2.5	<2.5	NA	<2.5	<2.5	<2.5	<0.01	7.8
MW-05	63-65'	104340	8/5/98	NA	NA	<0.025	<0.025	0.11	0.97	<2.5	0.21	<0.025	<0.025	<0.025	<2.5	<2.5	<2.5	<2.5	NA	<2.5	<2.5	<2.5	<0.01	<0.25
MW-06	3-5'	104532	8/6/98	NA	NA	<0.036	<0.036	<0.036	<0.036	<0.25	<0.036	<0.036	<0.036	<0.036	<0.25	<0.25	<0.25	<0.25	NA	<0.25	<0.25	<0.25	0.02	<0.01
MW-06	63-65'	104533	8/6/98	NA	NA	<0.059	<0.059	<0.059	<0.059	<0.25	<0.059	<0.059	<0.059	<0.059	<0.25	<0.25	<0.25	<0.25	NA	<0.25	<0.25	<0.25	<0.01	<0.01
MW-07	48-50'	104633	8/10/98	NA	NA	<0.025	<0.025	<0.025	<0.025	<0.25	<0.025	<0.025	<0.025	<0.025	<0.25	<0.25	<0.25	<0.25	NA	<0.25	<0.25	<0.25	0.01	17.62
MW-07	63-65'	104634	8/10/98	NA	NA	<0.025	<0.025	<0.025	<0.025	<0.25	<0.025	<0.025	<0.025	<0.025	<0.25	<0.25	<0.25	<0.25	NA	<0.25	<0.25	<0.25	0.02	4
MW-08	28-30'	104948	8/12/98	NA	NA	0.37	0.4	<0.025	<0.025	<0.25	<0.025	<0.025	0.41	0.42	<0.25	<0.25	<0.25	<0.25	NA	<0.25	<0.25	<0.25	<0.01	3.5
MW-08	63-65'	104949	8/12/98	NA	NA	<0.025	<0.025	<0.025	<0.025	<0.25	<0.025	<0.025	<0.025	<0.025	<0.25	<0.25	<0.25	<0.25	NA	<0.25	<0.25	<0.25	<0.01	1.5
MW-09D		109073	10/1/98	NA	NA	<0.001	<0.001	0.018	0.082	<0.001	0.027	<0.001	<0.001	<0.001	0.003	<0.001	<0.001	<0.001	NA	<0.001	<0.001	<0.001	<0.01	<0.01
MW Maxiumum				**NA**	**NA**	**0.37**	**0.4**	**2**	**8.7**	**ND**	**1.4**	**ND**	**0.41**	**0.42**	**2.9**	**2.85**	**ND**	**ND**	**NA**	**ND**	**ND**	**ND**	**0.08**	**310**
MW Average				**NA**	**NA**	**0.37**	**0.40**	**0.57**	**2.64**	**ND**	**0.45**	**ND**	**0.41**	**0.42**	**1.83**	**2.69**	**ND**	**ND**	**NA**	**ND**	**ND**	**ND**	**0.03**	**31.52**
MW Minimum				**NA**	**NA**	**0.37**	**0.4**	**0.018**	**0.082**	**ND**	**0.027**	**ND**	**0.41**	**0.42**	**0.003**	**2.52**	**ND**	**ND**	**NA**	**ND**	**ND**	**ND**	**0.01**	**0.25**

TABLE 2
1998 Soil Sample Detections
Hobbs, New Mexico

				S 8021B	S 8080	S 8260B			S 8260B						S 8270								SM 4500 CN, CE	SM 5530 A,D
Site Name	Sample Depth	Sample ID	Sample Date	Xylenes, Total	Solids, Percent	1,1-Dichloroethylene	Benzene	Ethylbenzene	m,p-xylene	Naphthalene	o-xylene	Tetrachloroethylene	Toluene	Trichloroethylene	1-Methylnaphthalene	2-Methylnaphthalene	Anthracene	Benzo(a)pyrene	bis(2-ethylhexyl)phthalate	Di(2-ethylhexyl)phthalate	Fluorene	Phenanthrene	Cyanide	Phenols, Total
			Unit	mg/Kg	mg/Kg	mg/Kg	mg/Kg	mg/Kg	mg/Kg	mg/Kg	mg/Kg	mg/Kg	mg/Kg	mg/Kg	mg/Kg	mg/Kg	mg/Kg	mg/Kg	mg/Kg	mg/Kg	mg/Kg	mg/Kg	mg/Kg	mg/Kg
SS-1	2-3'	T89559	1/20/98	NA	NA	<0.05	<0.05	<0.05	<0.05	<125	<0.05	<0.05	<0.05	<0.05	NA	<125	<125	<125	<125	NA	<125	<125	<0.25	NA
SS-1	5'	T89560	1/20/98	NA	NA	<0.05	<0.05	<0.05	<0.05	<25	<0.05	<0.05	<0.05	<0.05	NA	<25	<25	<25	<25	NA	<25	<25	<0.25	NA
SS-2	2-3'	T89561	1/20/98	NA	NA	<0.5	<0.5	7	31	<125	<0.5	<0.5	<0.5	<0.5	NA	<125	<125	<125	<125	NA	<125	<125	<0.25	NA
SS-2	6'	T89562	1/20/98	NA	NA	<0.5	<0.5	9.7	37	<50	<0.5	<0.5	<0.5	<0.5	NA	<50	<50	<50	<50	NA	<50	<50	<0.25	NA
SS-3	2-3'	T89563	1/20/98	NA	NA	<0.5	<0.5	1.4	4.9	<125	<0.5	<0.5	<0.5	<0.5	NA	<125	<125	<125	<125	NA	<125	<125	<0.25	NA
SS-3	5.5'	T89564	1/20/98	NA	NA	<0.1	<0.1	0.66	2	<125	<0.1	0.54	<0.1	<0.1	NA	<125	<125	<125	<125	NA	<125	<125	<0.25	NA
SS-4	1'	T89565	1/20/98	NA	NA	<0.025	<0.025	<0.025	<0.025	<25	<0.025	<0.025	<0.025	<0.025	NA	<25	<25	<25	<25	NA	<25	<25	<0.25	NA
SS-4	5'	T89566	1/20/98	NA	NA	<0.025	<0.025	<0.025	<0.025	<25	<0.025	<0.025	<0.025	<0.025	NA	<25	<25	<25	<25	NA	<25	<25	<0.25	NA
SS-5	2'	T89567	1/20/98	NA	NA	<0.05	<0.05	0.1	0.13	<25	<0.05	<0.05	<0.05	<0.05	NA	<25	<25	<25	<25	NA	<25	<25	<0.25	NA
SS-5	5'	T89568	1/20/98	NA	NA	<0.5	<0.5	9.2	39	<25	<0.5	<0.5	<0.5	<0.5	NA	<25	<25	<25	<25	NA	<25	<25	<0.25	NA
SS Maxiumum				**NA**	**NA**	**ND**	**ND**	**9.7**	**39**	**ND**	**ND**	**0.54**	**ND**	**ND**	**NA**	**ND**	**ND**	**ND**	**ND**	**NA**	**ND**	**ND**	**ND**	**NA**
SS Average				**NA**	**NA**	**ND**	**ND**	**4.68**	**19.01**	**ND**	**ND**	**0.54**	**ND**	**ND**	**NA**	**ND**	**ND**	**ND**	**ND**	**NA**	**ND**	**ND**	**ND**	**NA**
SS Minimum				**NA**	**NA**	**ND**	**ND**	**0.1**	**0.13**	**ND**	**ND**	**0.54**	**ND**	**ND**	**NA**	**ND**	**ND**	**ND**	**ND**	**NA**	**ND**	**ND**	**ND**	**NA**
TMW-1		109052	10/1/98	NA	NA	<0.001	0.002	<0.001	0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	NA	<0.001	<0.001	<0.001	<0.01	<0.01
TMW-1	2-3'	105742	8/19/98	NA	NA	<2	<2	10.9	43.6	<12.5	<2	<2	<2	<2	<12.5	<12.5	<12.5	<12.5	NA	<12.5	<12.5	<12.5	<0.01	0.04
TMW-1	63-65'	105743	8/19/98	NA	NA	<0.043	<0.043	<0.043	<0.043	<0.25	<0.043	<0.043	<0.043	<0.043	20	17.9	<0.25	<0.25	NA	<0.25	<0.25	<0.25	<0.01	0.11
TMW-1A	63-65'	105744	8/19/98	NA	NA	<0.055	<0.055	<0.055	<0.055	<0.25	<0.055	<0.055	<0.055	<0.055	20	17.9	<0.25	<0.25	NA	<0.25	<0.25	<0.25	<0.01	<0.01
TMW-2		109054	10/1/98	NA	NA	<0.001	0.002	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	NA	<0.001	<0.001	<0.001	<0.01	0.1
TMW-2	53-55'	105614	8/18/98	NA	NA	<0.025	<0.025	<0.025	<0.025	<0.25	<0.025	<0.025	<0.025	<0.025	<0.25	<0.25	<0.25	<0.25	NA	<0.25	<0.25	<0.25	<0.01	2.25
TMW-2	63-65'	105615	8/18/98	NA	NA	<0.025	<0.025	<0.025	<0.025	<0.25	<0.025	<0.025	<0.025	<0.025	<0.25	<0.25	<0.25	<0.25	NA	<0.25	<0.25	<0.25	<0.01	<0.25
TMW-3		109056	10/1/98	NA	NA	<0.001	<0.001	0.001	0.005	<0.001	0.002	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	NA	<0.001	<0.001	<0.001	<0.01	0.5
TMW-3	2-3'	108238	9/22/98	NA	NA	<0.07	0.074	<0.07	<0.07	<2.5	<0.07	<0.07	<0.07	<0.07	<2.5	<2.5	<2.5	<2.5	NA	<2.5	<2.5	<2.5	<0.01	<0.25
TMW-3	23-25'	108240	9/22/98	NA	NA	<0.1	0.12	3	11.5	3.41	<0.1	<0.1	<0.1	<0.1	<2.5	7.52	<2.5	8.81	NA	<2.5	<2.5	<2.5	<0.01	<0.25
TMW-3	3-5'	108239	9/22/98	NA	NA	<0.048	0.073	<0.048	<0.048	<2.5	<0.048	<0.048	<0.048	<0.048	<2.5	<2.5	<2.5	<2.5	NA	<2.5	<2.5	<2.5	<0.01	<0.25
TMW-3	63-65'	108241	9/22/98	NA	NA	<0.036	0.057	<0.036	<0.036	<0.25	<0.036	<0.036	<0.036	<0.036	<0.25	<0.25	<0.25	<0.25	NA	<0.25	<0.25	<0.25	<0.01	<0.25
TMW Maxiumum				**NA**	**NA**	**ND**	**0.12**	**10.9**	**43.6**	**3.41**	**0.002**	**ND**	**ND**	**ND**	**20**	**17.9**	**ND**	**8.81**	**NA**	**ND**	**ND**	**ND**	**ND**	**2.25**
TMW Average				**NA**	**NA**	**ND**	**0.10**	**4.63**	**13.78**	**3.41**	**0.00**	**ND**	**ND**	**ND**	**20.00**	**14.44**	**ND**	**8.81**	**NA**	**ND**	**ND**	**ND**	**ND**	**0.60**
TMW Minimum				**NA**	**NA**	**ND**	**0.074**	**0.001**	**0.001**	**3.41**	**0.002**	**ND**	**ND**	**ND**	**20**	**7.52**	**ND**	**8.81**	**NA**	**ND**	**ND**	**ND**	**ND**	**0.04**
TSB-01	2-3'	105955	8/20/98	NA	NA	<0.034	<0.034	<0.034	<0.034	<25	<0.034	<0.034	<0.034	<0.034	<25	<25	<25	<25	NA	<25	<25	<25	<0.01	6.25
TSB-01	3-5'	105956	8/20/98	NA	NA	<0.418	<0.418	11.1	<0.418	<0.25	1.9	<0.418	<0.418	<0.418	20	17.9	<0.25	<0.25	NA	<0.25	<0.25	<0.25	<0.01	4.25
TSB-01	43-45'	105961	9/10/98	NA	NA	NA	<0.05	<0.00005	NA	NA	NA	NA	<0.05	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
TSB-01	8-10'	105957	8/24/98	NA	NA	<0.051	<0.051	<0.051	<0.051	<2.5	<0.051	<0.051	<0.051	<0.051	<2.5	<2.5	<2.5	<2.5	NA	<2.5	<2.5	<2.5	<0.01	<0.25
TSB-02	18-20'	105960	8/20/98	NA	NA	<0.066	<0.066	<0.066	<0.066	<0.25	<0.066	<0.066	<0.066	<0.066	<0.25	<0.25	<0.25	<0.25	NA	<0.25	<0.25	<0.25	<0.01	3
TSB-02	2-3'	105958	8/20/98	NA	NA	<0.041	<0.041	<0.041	<0.041	<0.25	<0.041	<0.041	<0.041	<0.041	<0.25	<0.25	<0.25	<0.25	NA	<0.25	<0.25	<0.25	<0.01	4.25
TSB-02	3-5'	105959	8/20/98	NA	NA	<0.053	<0.053	<0.053	<0.053	<0.25	<0.053	<0.053	<0.053	<0.053	<0.25	<0.25	<0.25	<0.25	NA	<0.25	<0.25	<0.25	<0.01	1.75
TSB-03	18-20'	106198	8/20/98	NA	NA	<0.025	<0.025	<0.025	<0.025	<0.25	<0.025	<0.025	<0.025	<0.025	<0.25	<0.25	<0.25	<0.25	NA	<0.25	<0.25	<0.25	<0.01	<0.25
TSB-03	2-3'	106196	8/20/98	NA	97.8	<0.087	<0.087	<0.087	<0.087	<0.25	<0.087	<0.087	<0.087	<0.087	<0.25	<0.25	<0.25	<0.25	NA	<0.25	<0.25	<0.25	<0.01	<0.25
TSB-03	3-5'	106197	8/20/98	NA	NA	<0.035	<0.035	<0.035	<0.035	<0.25	<0.035	<0.035	<0.035	<0.035	<0.25	<0.25	<0.25	<0.25	NA	<0.25	<0.25	<0.25	<0.01	11.7
TSB-04	18-20'	106093	8/20/98	NA	NA	<0.028	<0.028	<0.028	<0.028	<0.25	<0.028	<0.028	<0.028	<0.028	<0.25	<0.25	<0.25	<0.25	NA	<0.25	<0.25	<0.25	<0.01	<0.25
TSB-04	18-20'	118969	8/20/98	NA	NA	NA	NA	NA	NA	<0.25	NA	NA	NA	NA	<0.25	<0.25	<0.25	<0.25	NA	<0.25	<0.25	<0.25	NA	NA
TSB-04	2-3'	106091	8/20/98	NA	NA	<0.045	<0.045	<0.045	0.063	<0.25	<0.045	<0.045	<0.045	<0.045	<0.25	<0.25	<0.25	<0.25	NA	<0.25	<0.25	<0.25	<0.01	52.3
TSB-04	2-3'	118967	8/20/98	NA	NA	NA	NA	NA	NA	<0.25	NA	NA	NA	NA	<0.25	<0.25	<0.25	<0.25	NA	<0.25	<0.25	<0.25	NA	NA
TSB-04	3-5'	106092	8/20/98	NA	NA	<0.101	<0.101	<0.101	<0.101	<0.25	<0.101	<0.101	0.27	<0.101	<0.25	<0.25	<0.25	<0.25	NA	<0.25	<0.25	<0.25	<0.01	<0.25
TSB-04	3-5'	118968	8/20/98	NA	NA	NA	NA	NA	NA	<0.25	NA	NA	NA	NA	<0.25	<0.25	<0.25	<0.25	NA	<0.25	<0.25	<0.25	NA	NA
TSB-05	18-20'	106096	9/1/98	NA	NA	<0.054	<0.054	<0.054	<0.054	<0.25	<0.054	<0.054	<0.054	<0.054	<0.25	<0.25	<0.25	<0.25	NA	<0.25	<0.25	<0.25	<0.01	102
TSB-05	18-20'	118972	9/1/98	NA	NA	NA	NA	NA	NA	<0.25	NA	NA	NA	NA	<0.25	<0.25	<0.25	<0.25	NA	<0.25	<0.25	<0.25	NA	NA
TSB-05	2-3'	106094	9/1/98	NA	NA	<0.034	<0.034	<0.034	<0.034	<0.25	<0.034	<0.034	<0.034	<0.034	<0.25	<0.25	<0.25	<0.25	NA	<0.25	<0.25	<0.25	<0.01	<0.25

TABLE 2
1998 Soil Sample Detections
Hobbs, New Mexico

				S 8021B	S 8080	S 8260B			S 8260B						S 8270								SM 4500 CN, CE	SM 5530 A,D
Site Name	Sample Depth	Sample ID	Sample Date	Xylenes, Total	Solids, Percent	1,1-Dichloroethylene	Benzene	Ethylbenzene	m,p-xylene	Naphthalene	o-xylene	Tetrachloroethylene	Toluene	Trichloroethylene	1-Methylnaphthalene	2-Methylnaphthalene	Anthracene	Benzo(a)pyrene	bis(2-ethylhexyl)phthalate	Di(2-ethylhexyl)phthalate	Fluorene	Phenanthrene	Cyanide	Phenols, Total
			Unit	mg/Kg	mg/Kg	mg/Kg	mg/Kg	mg/Kg	mg/Kg	mg/Kg	mg/Kg	mg/Kg	mg/Kg	mg/Kg	mg/Kg	mg/Kg	mg/Kg	mg/Kg	mg/Kg	mg/Kg	mg/Kg	mg/Kg	mg/Kg	mg/Kg
TSB-05	2-3'	118970	9/1/98	NA	NA	NA	NA	NA	NA	<0.25	NA	NA	NA	NA	<0.25	<0.25	<0.25	<0.25	NA	0.38	<0.25	<0.25	NA	NA
TSB-05	3-5'	106095	9/1/98	NA	NA	<0.06	<0.06	<0.06	<0.06	<0.25	<0.06	<0.06	<0.06	<0.06	<0.25	<0.25	<0.25	<0.25	NA	<0.25	<0.25	<0.25	<0.01	<0.25
TSB-05	3-5'	118971	9/1/98	NA	NA	NA	NA	NA	NA	<0.25	NA	NA	NA	NA	<0.25	<0.25	<0.25	<0.25	NA	0.38	<0.25	<0.25	NA	NA
TSB-06	18-20'	106033	9/1/98	NA	NA	<0.058	<0.058	<0.058	0.072	<0.25	<0.058	<0.058	<0.058	<0.058	<0.25	<0.25	<0.25	<0.25	NA	<0.25	<0.25	<0.25	<0.01	2.3
TSB-06	18-20'	118877	9/1/98	NA	NA	NA	NA	NA	NA	7.6	NA	NA	NA	NA	16	17	<1.5	<1.5	NA	<1.5	1.8	3.3	NA	NA
TSB-06	2-3'	106034	9/1/98	NA	NA	<0.061	<0.061	<0.061	<0.061	<12.5	<0.061	<0.061	<0.061	<0.061	<12.5	<12.5	<12.5	<12.5	NA	<12.5	<12.5	<12.5	<0.01	<0.25
TSB-06	2-3'	118875	9/1/98	NA	NA	NA	NA	NA	NA	<1.5	NA	NA	NA	NA	<1.5	<1.5	<1.5	<1.5	NA	<1.5	<1.5	<1.5	NA	NA
TSB-06	3-5'	106035	9/1/98	NA	NA	<0.068	<0.068	<0.068	<0.068	<2.5	<0.068	<0.068	<0.068	<0.068	<2.5	<2.5	<2.5	<2.5	NA	<2.5	<2.5	<2.5	<0.01	<0.25
TSB-06	3-5'	118876	9/1/98	NA	NA	NA	NA	NA	NA	<0.75	NA	NA	NA	NA	<0.75	<0.75	<0.75	<0.75	NA	<0.75	<0.75	<0.75	NA	NA
TSB-07	2-3'	106036	9/1/98	NA	NA	<0.232	0.71	5.7	15	<5	0.66	<0.232	1	<0.232	<5	<5	<5	<5	NA	<5	<5	<5	<0.01	4.8
TSB-07	2-3'	118880	9/1/98	NA	NA	NA	NA	NA	NA	<25	NA	NA	NA	NA	43	39	<25	<25	NA	<25	<25	<25	NA	NA
TSB-07	2-3'	99A1348	9/1/98	NA	NA	NA	0.02	3.2	12	NA	0.1	NA	0.012	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
TSB-07	28-30'	106028	8/27/98	NA	NA	NA	<0.05	<0.00005	NA	NA	NA	NA	<0.05	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
TSB-07	28-30'	118883	9/1/98	NA	NA	NA	NA	NA	NA	<0.25	NA	NA	NA	NA	<0.25	<0.25	<0.25	<0.25	NA	<0.25	<0.25	<0.25	NA	NA
TSB-07	3-5'	106037	9/1/98	NA	NA	<0.252	<0.252	9.9	41	<5	<0.252	<0.252	<0.252	<0.252	<5	<5	<5	<5	NA	<5	<5	<5	<0.01	4.3
TSB-07	3-5'	118881	9/1/98	NA	NA	NA	NA	NA	NA	<7.5	NA	NA	NA	NA	15	14	<7.5	<7.5	NA	<7.5	<7.5	<7.5	NA	NA
TSB-07	8-10'	106038	9/1/98	NA	NA	<0.078	<0.078	0.6	2.1	<25	0.089	<0.078	<0.078	<0.078	<25	<25	<25	<25	NA	<25	<25	<25	<0.01	3.8
TSB-07	8-10'	118882	9/1/98	NA	NA	NA	NA	NA	NA	<0.25	NA	NA	NA	NA	<0.25	<0.25	<0.25	<0.25	NA	<0.25	<0.25	<0.25	NA	NA
TSB-08	2-3'	105408	9/1/98	NA	NA	<1.35	<1.35	17	<1.35	<2.5	5.6	<1.35	<1.35	<1.35	<2.5	<2.5	<2.5	<2.5	NA	<2.5	<2.5	<2.5	<0.01	0.07
TSB-08	2-3'	99A1349	9/1/98	NA	NA	NA	0.0098	11	48	NA	0.24	NA	0.0065	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
TSB-08	3-5'	107006	9/1/98	NA	NA	<2.48	<2.48	12	36	<2.5	<2.48	<2.48	<2.48	<2.48	5	4.9	<2.5	<2.5	NA	<2.5	<2.5	<2.5	<0.01	7.7
TSB-08	40-42'	107009	9/1/98	NA	NA	<0.08	<0.08	<0.08	<0.08	<0.25	<0.08	<0.08	<0.08	<0.08	<0.25	<0.25	<0.25	<0.25	NA	<0.25	<0.25	<0.25	<0.01	0.64
TSB-08	8-10'	107008	9/1/98	NA	NA	<0.104	<0.104	2.5	9.8	<12.5	<0.104	<0.104	<0.104	<0.104	<12.5	<12.5	<12.5	<12.5	NA	<12.5	<12.5	<12.5	<0.01	2.8
TSB-08D	3-5'	107007	9/1/98	NA	NA	<1.25	<1.25	12	40	<12.5	<1.25	<1.25	<1.25	<1.25	33	35	<12.5	<12.5	NA	<12.5	<12.5	<12.5	<0.01	6.2
TSB-09	18-20'	106099	9/1/98	NA	NA	<0.129	<0.129	<0.129	<0.129	<0.25	<0.129	<0.129	<0.129	<0.129	<0.25	<0.25	<0.25	<0.25	NA	<0.25	<0.25	<0.25	<0.01	<0.25
TSB-09	18-20'	120215	9/1/98	NA	NA	NA	NA	NA	NA	<0.25	NA	NA	NA	NA	<0.25	<0.25	<0.25	<0.25	NA	<0.25	<0.25	<0.25	NA	NA
TSB-09	2-3'	106097	9/1/98	NA	NA	<0.069	<0.069	<0.069	<0.069	<0.25	<0.069	<0.069	<0.069	<0.069	<0.25	<0.25	<0.25	<0.25	NA	<0.25	<0.25	<0.25	<0.01	<0.25
TSB-09	2-3'	120213	9/1/98	NA	NA	NA	NA	NA	NA	<0.25	NA	NA	NA	NA	<0.25	<0.25	<0.25	<0.25	NA	<0.25	<0.25	<0.25	NA	NA
TSB-09	3-5'	106098	9/1/98	NA	NA	<0.037	<0.037	<0.037	<0.037	<0.25	<0.037	<0.037	<0.037	<0.037	<0.25	<0.25	<0.25	<0.25	NA	<0.25	<0.25	<0.25	<0.01	<0.25
TSB-09	3-5'	120214	9/1/98	NA	NA	NA	NA	NA	NA	<0.25	NA	NA	NA	NA	<0.25	<0.25	<0.25	<0.25	NA	<0.25	<0.25	<0.25	NA	NA
TSB-09	48-50'	120216	9/1/98	NA	NA	NA	NA	NA	NA	<0.25	NA	NA	NA	NA	<0.25	<0.25	<0.25	<0.25	NA	<0.25	<0.25	<0.25	NA	NA
TSB-10	2-3'	106029	9/1/98	NA	NA	<0.63	<0.63	1.35	1.71	<12.5	<0.63	<0.63	<0.63	<0.63	<12.5	<12.5	<12.5	<12.5	NA	<12.5	<12.5	<12.5	<0.25	3.5
TSB-10	2-3'	118884	9/1/98	NA	NA	NA	NA	NA	NA	<25	NA	NA	NA	NA	<25	<25	<25	<25	NA	<25	<25	<25	NA	NA
TSB-10	28-30'	118887	9/1/98	NA	NA	NA	NA	NA	NA	<0.25	NA	NA	NA	NA	<0.25	<0.25	<0.25	<0.25	NA	<0.25	<0.25	<0.25	NA	NA
TSB-10	3-5'	106030	9/1/98	NA	NA	<1.88	<1.88	11	20	<12.5	<1.88	<1.88	<1.88	<1.88	<12.5	<12.5	<12.5	<12.5	NA	<12.5	<12.5	<12.5	<0.25	22.8
TSB-10	3-5'	118885	9/1/98	NA	NA	NA	NA	NA	NA	<7.5	NA	NA	NA	NA	13	14	<7.5	<7.5	NA	<7.5	<7.5	<7.5	NA	NA
TSB-10	8-10'	118886	9/1/98	NA	NA	NA	NA	NA	NA	<3.75	NA	NA	NA	NA	8.5	8.7	<3.75	<3.75	NA	<3.75	<3.75	<3.75	NA	NA
TSB-11	18-20'	106102	9/1/98	NA	NA	<0.38	<0.38	1.4	4.4	8.02	<0.38	<0.38	<0.38	<0.38	14.9	8.02	2.97	<0.25	NA	<0.25	1.64	<0.25	<0.01	1.31
TSB-11	18-20'	118978	9/1/98	NA	NA	NA	NA	NA	NA	<1.25	NA	NA	NA	NA	19	20	<1.25	<1.25	NA	<1.25	<1.25	<1.25	NA	NA
TSB-11	2-3'	106100	9/1/98	NA	NA	<0.103	<0.103	<0.103	<0.103	<1.25	<0.103	<0.103	<0.103	<0.103	<1.25	<1.25	<1.25	<1.25	NA	<1.25	<1.25	<1.25	<0.01	<0.25
TSB-11	2-3'	118976	9/1/98	NA	NA	NA	NA	NA	NA	<1.25	NA	NA	NA	NA	<1.25	<1.25	<1.25	<1.25	NA	<1.25	<1.25	<1.25	NA	NA
TSB-11	29-31'	106103	9/1/98	NA	NA	<0.037	<0.037	<0.037	<0.037	<0.25	<0.037	<0.037	<0.037	<0.037	<0.25	<0.25	<0.25	<0.25	NA	<0.25	<0.25	<0.25	<0.01	<0.25
TSB-11	29-31'	118979	9/1/98	NA	NA	NA	NA	NA	NA	<0.25	NA	NA	NA	NA	<0.25	<0.25	<0.25	<0.25	NA	<0.25	<0.25	<0.25	NA	NA
TSB-11	3-5'	106101	9/1/98	NA	NA	<0.058	<0.058	<0.058	<0.058	<0.25	<0.058	<0.058	<0.058	<0.058	<0.25	<0.25	<0.25	<0.25	NA	<0.25	<0.25	<0.25	<0.01	<0.25
TSB-11	3-5'	118977	9/1/98	NA	NA	NA	NA	NA	NA	<1.25	NA	NA	NA	NA	<1.25	<1.25	<1.25	<1.25	NA	<1.25	<1.25	<1.25	NA	NA
TSB-12	18-20'	106201	9/1/98	NA	90.2	<0.025	<0.025	<0.025	<0.025	<0.25	<0.025	<0.025	<0.025	<0.025	4.99	3.75	<0.25	<0.25	NA	<0.25	0.832	2.41	<0.01	1.15
TSB-12	2-3'	106199	9/1/98	NA	95.6	<0.025	<0.025	<0.025	<0.025	<0.25	<0.025	<0.025	<0.025	<0.025	<0.25	<0.25	<0.25	<0.25	NA	<0.25	<0.25	<0.25	<0.01	<0.25
TSB-12	3-5'	106200	9/1/98	NA	92.7	<0.025	<0.025	<0.025	<0.025	<0.25	<0.025	<0.025	<0.025	<0.025	<0.25	<0.25	<0.25	<0.25	NA	<0.25	<0.25	<0.25	<0.01	1.5
TSB-12	48-50'	106202	9/1/98	NA	NA	<0.025	<0.025	<0.025	<0.025	<0.25	<0.025	<0.025	<0.025	<0.025	<0.25	<0.25	<0.25	<0.25	NA	<0.25	<0.25	<0.25	<0.01	6.08
TSB-13	2-3'	106824	9/1/98	NA	NA	<0.025	<0.025	<0.025	<0.025	<2.5	<0.025	<0.025	<0.025	<0.025	<2.5	<2.5	<2.5	<2.5	NA	<2.5	<2.5	<2.5	<0.01	2.8
TSB-13	23-25'	106827	9/1/98	NA	NA	<0.053	<0.053	<0.053	<0.053	<0.25	<0.053	<0.053	<0.053	<0.053	<0.25	<0.25	<0.25	<0.25	NA	<0.25	<0.25	<0.25	<0.01	4.2
TSB-13	3-5'	106825	9/1/98	NA	NA	<0.021	<0.021	<0.021	<0.021	<2.5	<0.021	<0.021	<0.021	<0.021	<2.5	<2.5	<2.5	<2.5	NA	<2.5	<2.5	<2.5	<0.01	2.5
TSB-13	8-10'	106826	9/1/98	NA	NA	<0.027	<0.027	<0.027	<0.027	<2.5	<0.027	<0.027	<0.027	<0.027	6.31	5.45	<2.5	<2.5	NA	<2.5	<2.5	<2.5	<0.01	1.5
TSB-14	18-20'	104099b	8/1/98	NA	NA	<0.025	<0.025	<0.025	<0.025	<0.25	<0.025	<0.025	<0.025	<0.025	<0.25	<0.25	<0.25	<0.25	NA	<0.25	<0.25	<0.25	0.01	6.5
TSB-14	40-42'	118283	8/1/98	NA	93.4	<0.112	<0.112	2	12	3.6	<0.112	<0.112	<0.112	<0.112	9.6	7.9	<1.25	<1.25	NA	<1.25	<1.25	1.94	<0.2	2.49
TSB-14	63-65'	104100b	8/1/98	NA	NA	<0.025	<0.025	<0.025	<0.025	<0.25	<0.025	<0.025	<0.025	<0.025	<0.25	<0.25	<0.25	<0.25	NA	<0.25	<0.25	<0.25	0.07	2.75
TSB-14	63-65'	118284	8/1/98	NA	89.4	<0.026	<0.026	<0.026	<0.026	<0.25	<0.026	<0.026	<0.026	<0.026	<0.25	<0.25	<0.25	<0.25	NA	<0.25	<0.25	<0.25	<0.2	12.4
TSB Maxiumum				**NA**	**97.8**	**ND**	**0.71**	**17**	**48**	**8.02**	**1.9**	**ND**	**1**	**ND**	**43**	**39**	**2.97**	**ND**	**NA**	**0.38**	**1.8**	**3.3**	**0.07**	**102**
TSB Average				**NA**	**93.18**	**ND**	**0.25**	**7.20**	**18.62**	**6.41**	**0.60**	**ND**	**0.32**	**ND**	**16.02**	**15.05**	**2.97**	**ND**	**NA**	**0.38**	**1.42**	**2.55**	**0.04**	**9.34**
TSB Minimum				**NA**	**89.4**	**ND**	**0.0098**	**0.6**	**0.063**	**3.6**	**0.089**	**ND**	**0.0065**	**ND**	**4.99**	**3.75**	**2.97**	**ND**	**NA**	**0.38**	**0.832**	**1.94**	**0.01**	**0.07**

NOTES:

NA = Sample not analyzed for this constituer

ND = Constituent not detected at method de

TABLE 3
Soil Gas Detections - Large Scale Survey
July-August 1998, Westgate Subdivision, Hobbs, New Mexico

Well	Depth	Date	Benzene mg/L	Butane mg/L	Ethane mg/L	Ethylbenzene mg/L	Hexane mg/L	Methane mg/L	Pentane mg/L	Propane mg/L	Toluene mg/L	TPH mg/L	Xylenes, Total mg/L
Samples With TPH Detections													
TSVA	7	8/17/98	ND	ND	ND	55	12	NA	ND	ND	33	3000	300
TSVI	7	8/17/98	ND	ND	1	ND	ND	NA	ND	ND	ND	3000	ND
TSVB	5	8/17/98	ND	ND	ND	30	ND	NA	ND	ND	20	2000	200
TSVX	3	8/20/98	11	1	4	14	6	NA	1	1	60	1500	54
SV-024	5	7/29/98	ND	ND	ND	ND	ND	3	ND	ND	ND	700	ND
SV-039	5	7/28/98	1	ND	1	10	ND	16	ND	ND	35	600	65
SV-238	5	7/28/98	1	4	5	ND	19	NA	17	2	6	200	7
SV-239	5	8/19/98	ND	ND	ND	ND	2	NA	ND	ND	ND	200	ND
TSVZ	5	8/19/98	4	ND	2	10	ND	NA	ND	ND	24	100	38
TSVM	5	8/17/98	ND	ND	1	ND	ND	NA	ND	ND	ND	100	ND
TSVS	5	8/19/98	ND	ND	ND	2	ND	NA	ND	ND	1	70	6
TSVY	5	8/19/98	ND	ND	2	1	ND	NA	ND	1	1	50	3
SV-158	5	8/10/98	ND	140	1000	ND	6	NA	24	800	ND	40	ND
SV-164	5	8/3/98	ND	ND	ND	ND	ND	NA	ND	ND	ND	37	ND
TSVQ	1	8/18/98	ND	ND	ND	ND	ND	NA	ND	ND	ND	20	ND
TSVAA	5	8/20/98	ND	ND	2	ND	ND	NA	ND	ND	ND	17	ND
SV-025	5	7/29/98	ND	ND	ND	ND	ND	5	ND	ND	ND	13	ND
TSVL	5	8/17/98	ND	ND	ND	ND	ND	NA	ND	ND	ND	10	3
SV-111	5	8/13/98	ND	ND	ND	ND	ND	NA	ND	ND	ND	9	ND
SV-187	5	8/10/98	ND	ND	ND	ND	ND	NA	ND	ND	ND	7	ND
SV-026	5	7/29/98	ND	ND	1	ND	ND	20	ND	ND	ND	7	ND
SV-053	5	7/28/98	ND	ND	1	ND	ND	10	ND	ND	ND	7	1
SV-180	5	8/5/98	ND	ND	1	ND	ND	NA	ND	ND	ND	4	ND
SV-049	5	7/29/98	ND	ND	ND	ND	ND	20	ND	ND	ND	4	ND
SV-160	5	8/7/98	ND	ND	1	ND	ND	NA	ND	ND	ND	3	ND
SV-162	5	8/11/98	ND	ND	3	ND	ND	NA	ND	ND	ND	3	ND
SV-178	5	8/3/98	ND	ND	ND	ND	ND	NA	ND	ND	ND	3	ND
SV-240	5	8/19/98	ND	ND	ND	ND	ND	NA	ND	ND	ND	3	ND
TSVK	5	8/17/98	ND	ND	ND	ND	ND	NA	ND	ND	ND	3	2
SV-050	5	7/29/98	ND	ND	ND	ND	ND	6	ND	ND	ND	3	ND
SV-052	5	7/29/98	ND	ND	ND	ND	ND	5	ND	ND	ND	3	ND
SV-051	5	7/29/98	ND	ND	ND	ND	ND	3	ND	ND	ND	3	ND
SV-171	5	8/7/98	ND	ND	3	ND	ND	NA	ND	1	ND	2	ND
SV-177	5	8/4/98	ND	ND	1	ND	ND	NA	ND	ND	ND	2	ND
SV-185	5	8/7/98	ND	ND	ND	ND	ND	NA	ND	ND	ND	2	ND
SV-206	5	8/3/98	ND	ND	ND	ND	ND	NA	ND	ND	ND	2	ND
TSVF	5	8/17/98	ND	ND	ND	ND	ND	NA	ND	ND	ND	2	ND
TSVR	5	8/19/98	ND	ND	ND	ND	ND	NA	ND	ND	ND	2	ND
SV-017	5	7/27/98	ND	ND	ND	ND	ND	56	ND	ND	ND	2	ND
SV-002	5	7/28/98	ND	ND	3	ND	ND	45	ND	ND	ND	2	ND
SV-048	5	7/29/98	ND	ND	ND	ND	ND	5	ND	ND	ND	2	ND
SV-193	5	8/5/98	NA	NA	ND	NA	NA	NA	NA	NA	NA	1	NA
SV-194	5	8/5/98	NA	NA	1	NA	NA	NA	NA	NA	NA	1	NA
SV-098	5	8/11/98	ND	ND	ND	ND	ND	NA	ND	ND	ND	1	ND
SV-102	5	8/13/98	ND	ND	1	ND	ND	NA	ND	ND	ND	1	ND
SV-105	5	8/18/98	ND	1	3	ND	ND	NA	ND	1	ND	1	ND
SV-107	5	8/13/98	ND	ND	ND	ND	ND	NA	ND	ND	ND	1	ND
SV-141	5	8/18/98	ND	ND	ND	ND	ND	NA	ND	ND	ND	1	ND
SV-150	5	8/18/98	ND	ND	ND	ND	ND	NA	ND	ND	ND	1	ND
SV-154	5	8/5/98	ND	ND	ND	ND	2	NA	ND	ND	ND	1	ND
SV-161	5	8/6/98	ND	ND	ND	ND	ND	NA	ND	ND	ND	1	ND
SV-166	5	8/5/98	ND	ND	ND	ND	ND	NA	ND	ND	ND	1	ND
SV-167	5	8/3/98	ND	ND	ND	ND	ND	NA	ND	ND	ND	1	ND
SV-168	5	8/4/98	ND	ND	ND	ND	ND	NA	ND	ND	ND	1	ND
SV-175	5	8/6/98	ND	ND	ND	ND	ND	NA	ND	ND	ND	1	ND
SV-179	5	8/5/98	ND	ND	ND	ND	ND	NA	ND	ND	ND	1	ND

TABLE 3
Soil Gas Detections - Large Scale Survey
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Well	Depth	Date	Benzene mg/L	Butane mg/L	Ethane mg/L	Ethylbenzene mg/L	Hexane mg/L	Methane mg/L	Pentane mg/L	Propane mg/L	Toluene mg/L	TPH mg/L	Xylenes, Total mg/L
SV-184	5	8/6/98	ND	ND	ND	ND	4	NA	ND	ND	ND	1	ND
SV-191	5	8/4/98	ND	ND	ND	ND	ND	NA	ND	ND	ND	1	ND
SV-223	5	8/3/98	ND	ND	ND	ND	ND	NA	ND	ND	ND	1	ND
TSVN	5	8/17/98	ND	ND	ND	ND	ND	NA	ND	ND	ND	1	ND
TSVV	5	8/19/98	ND	ND	ND	ND	ND	NA	ND	ND	ND	1	2
SV-047	5	7/29/98	ND	ND	ND	ND	ND	7	ND	ND	ND	1	ND
Samples with Detections Other Than TPH													
SV-113	5	8/11/98	ND	ND	4.0	ND	ND	NA	ND	1.0	ND	ND	ND
SV-159	5	8/10/98	ND	ND	3.0	ND	ND	NA	ND	1.0	ND	ND	ND
SV-227	5	8/10/98	ND	ND	3.0	ND	ND	NA	ND	ND	ND	ND	ND
TSVJ	7	8/18/98	ND	ND	3.0	ND	ND	NA	ND	ND	ND	ND	ND
SV-080	5	8/19/98	ND	ND	2.0	ND	ND	NA	ND	ND	ND	ND	ND
SV-096	5	8/12/98	ND	ND	2.0	ND	ND	NA	ND	ND	ND	ND	ND
SV-237	5	8/12/98	ND	ND	2.0	ND	ND	NA	ND	ND	ND	ND	ND
SV-042	5	7/27/98	ND	ND	2.0	ND	ND	27.0	ND	ND	ND	ND	ND
SV-135	5	8/13/98	ND	ND	1.0	ND	ND	NA	ND	ND	ND	ND	ND
SV-136	5	8/11/98	ND	ND	1.0	ND	ND	NA	ND	ND	ND	ND	ND
SV-148	5	8/18/98	ND	ND	1.0	ND	ND	NA	ND	ND	ND	ND	ND
SV-149	5	8/19/98	ND	ND	1.0	ND	ND	NA	ND	ND	ND	ND	ND
SV-170	5	8/6/98	ND	ND	1.0	ND	ND	NA	ND	ND	ND	ND	ND
SV-173	5	8/10/98	ND	ND	1.0	ND	ND	NA	ND	ND	ND	ND	ND
SV-220	5	8/3/98	ND	ND	1.0	ND	ND	NA	ND	ND	ND	ND	ND
SV-191B	5	8/4/98	ND	ND	ND	ND	ND	NA	ND	ND	ND	ND	ND
SV-191C	5	8/4/98	ND	ND	ND	ND	ND	NA	ND	ND	ND	ND	ND
TSVT	5	8/19/98	ND	ND	ND	ND	ND	NA	ND	ND	ND	ND	1.0
TSVU	5	8/19/98	ND	ND	ND	ND	ND	NA	ND	ND	ND	ND	1.0
Samples with Methane Detections Only													
SV-001	5	7/28/98	NA	NA	ND	NA	NA	17.0	NA	NA	NA	ND	NA
SV-041	5	7/27/98	NA	NA	ND	NA	NA	17.0	NA	NA	NA	ND	NA
SV-015	5	7/27/98	NA	NA	ND	NA	NA	16.0	NA	NA	NA	ND	NA
SV-016	5	7/27/98	NA	NA	ND	NA	NA	16.0	NA	NA	NA	ND	NA
SV-018	5	7/27/98	NA	NA	ND	NA	NA	9.0	NA	NA	NA	ND	NA
SV-034	5	7/30/98	NA	NA	ND	NA	NA	9.0	NA	NA	NA	ND	NA
SV-055	5	7/27/98	NA	NA	ND	NA	NA	9.0	NA	NA	NA	ND	NA
SV-019	5	7/27/98	NA	NA	ND	NA	NA	8.0	NA	NA	NA	ND	NA
SV-027	5	7/30/98	NA	NA	ND	NA	NA	8.0	NA	NA	NA	ND	NA
SV-035	5	7/30/98	NA	NA	ND	NA	NA	8.0	NA	NA	NA	ND	NA
SV-036	5	7/30/98	NA	NA	ND	NA	NA	8.0	NA	NA	NA	ND	NA
SV-057	5	7/29/98	NA	NA	ND	NA	NA	8.0	NA	NA	NA	ND	NA
SV-003	5	7/28/98	NA	NA	ND	NA	NA	7.0	NA	NA	NA	ND	NA
SV-022	5	7/29/98	NA	NA	ND	NA	NA	7.0	NA	NA	NA	ND	NA
SV-032	5	7/30/98	NA	NA	ND	NA	NA	6.0	NA	NA	NA	ND	NA
SV-010	5	7/28/98	NA	NA	ND	NA	NA	5.0	NA	NA	NA	ND	NA
SV-020	5	7/28/98	NA	NA	ND	NA	NA	5.0	NA	NA	NA	ND	NA
SV-021	5	7/28/98	NA	NA	ND	NA	NA	5.0	NA	NA	NA	ND	NA
SV-033	5	7/30/98	NA	NA	ND	NA	NA	5.0	NA	NA	NA	ND	NA
SV-044	5	7/27/98	NA	NA	ND	NA	NA	5.0	NA	NA	NA	ND	NA
SV-054	5	7/27/98	NA	NA	ND	NA	NA	5.0	NA	NA	NA	ND	NA
SV-005	5	7/28/98	NA	NA	ND	NA	NA	4.0	NA	NA	NA	ND	NA
SV-012	5	7/28/98	NA	NA	ND	NA	NA	4.0	NA	NA	NA	ND	NA
SV-014	5	7/27/98	NA	NA	ND	NA	NA	4.0	NA	NA	NA	ND	NA
SV-023	5	7/29/98	NA	NA	ND	NA	NA	4.0	NA	NA	NA	ND	NA
SV-030	5	7/30/98	NA	NA	ND	NA	NA	4.0	NA	NA	NA	ND	NA
SV-056	5	7/29/98	NA	NA	ND	NA	NA	4.0	NA	NA	NA	ND	NA
SV-058	5	7/29/98	NA	NA	ND	NA	NA	4.0	NA	NA	NA	ND	NA
SV-059	5	7/29/98	NA	NA	ND	NA	NA	4.0	NA	NA	NA	ND	NA

TABLE 3
Soil Gas Detections - Large Scale Survey
July-August 1998, Westgate Subdivision, Hobbs, New Mexico

Well	Depth	Date	Benzene mg/L	Butane mg/L	Ethane mg/L	Ethylbenzene mg/L	Hexane mg/L	Methane mg/L	Pentane mg/L	Propane mg/L	Toluene mg/L	TPH mg/L	Xylenes, Total mg/L
SV-007	5	7/28/98	NA	NA	ND	NA	NA	3.0	NA	NA	NA	ND	NA
SV-008	5	7/28/98	NA	NA	ND	NA	NA	3.0	NA	NA	NA	ND	NA
SV-013	5	7/27/98	NA	NA	ND	NA	NA	3.0	NA	NA	NA	ND	NA
SV-028	5	7/30/98	NA	NA	ND	NA	NA	3.0	NA	NA	NA	ND	NA
SV-029	5	7/30/98	NA	NA	ND	NA	NA	3.0	NA	NA	NA	ND	NA
SV-031	5	7/30/98	NA	NA	ND	NA	NA	3.0	NA	NA	NA	ND	NA
SV-037	5	7/30/98	NA	NA	ND	NA	NA	3.0	NA	NA	NA	ND	NA
SV-038	5	7/30/98	NA	NA	ND	NA	NA	3.0	NA	NA	NA	ND	NA
SV-046	5	7/29/98	NA	NA	ND	NA	NA	3.0	NA	NA	NA	ND	NA
SV-004	5	7/28/98	NA	NA	ND	NA	NA	2.0	NA	NA	NA	ND	NA
SV-006	5	7/28/98	NA	NA	ND	NA	NA	2.0	NA	NA	NA	ND	NA
SV-009	5	7/28/98	NA	NA	ND	NA	NA	2.0	NA	NA	NA	ND	NA
SV-011	5	7/28/98	NA	NA	ND	NA	NA	2.0	NA	NA	NA	ND	NA
SV-040	5	7/27/98	NA	NA	ND	NA	NA	2.0	NA	NA	NA	ND	NA
SV-043	5	7/27/98	NA	NA	ND	NA	NA	2.0	NA	NA	NA	ND	NA
SV-060	5	7/29/98	NA	NA	ND	NA	NA	2.0	NA	NA	NA	ND	NA
SV-045	5	7/29/98	NA	NA	ND	NA	NA	1.0	NA	NA	NA	ND	NA

Notes:

Samples not listed contained no detections.

NA = Sample not analyzed for this constituent.

ND = Constituent not detected at method detection limit.

TABLE 4
1999 Soil Sample Detections
Hobbs, New Mexico
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				E 150.1	E 160.1	E 300.0				E 418.1	E 901.1M					S 6010B															
Site Name	Sample Depth	Sample ID	Sample Date	pH	TDS	Chloride	Fluoride	Nitrate	Sulfate	TRPHC	Lead	Radium, Total	Radium-226	Radium-228	Total Activity	Aluminum	Antimony	Arsenic	Barium	Beryllium	Boron	Cadmium	Calcium	Chromium	Cobalt	Copper	Iron	Lead	Magnesium	Manganese	Mercury, Total
			Unit		mg/Kg	mg/Kg	mg/Kg	mg/Kg	mg/Kg	mg/Kg	pCi/gm	pCi/gm	pCi/gm	pCi/gm	pCi/gm	mg/Kg	mg/Kg	mg/Kg	mg/Kg	mg/Kg	mg/Kg	mg/Kg	mg/Kg	mg/Kg	mg/Kg	mg/Kg	mg/Kg	mg/Kg	mg/Kg	mg/Kg	mg/Kg
															0																
Maximum of All Samples				**9.2**	**6200**	**1100**	**6.1**	**29**	**3000**	**52000**	**2.35**	**11.03**	**2.25**	**0.7**	**17.19**	**12400**	**5**	**5.5**	**1020**	**0.4**	**78**	**1.5**	**50900**	**14**	**9.7**	**21**	**11000**	**17**	**2020**	**257**	**0.17**
Average of All Samples				**8.39**	**1127.94**	**99.79**	**1.99**	**5.39**	**389.3**	**10245**	**2.35**	**2.82**	**1.98**	**0.68**	**9.96**	**5289.24**	**5**	**2.19**	**173.35**	**0.4**	**28.29**	**0.56**	**38567**	**5.43**	**3.66**	**5.64**	**4394.05**	**5.18**	**1900**	**90.91**	**0.125**
Minimum of All Samples				**5.6**	**190**	**10**	**0.56**	**1.4**	**6.7**	**51.7**	**2.35**	**0.2**	**1.82**	**0.66**	**4.37**	**990**	**5**	**1**	**5.5**	**0.4**	**11**	**0.19**	**30200**	**1.6**	**0.61**	**1.5**	**7.21**	**0.52**	**1710**	**8.5**	**0.1**
															0																
GBN-1	6'	117626	1/24/99	7.6	1300	49	0.56	12	140	8570	<2.23	2.91	2.25	0.66	8.32	7270	NA	<0.5	206	NA	25	1.5	NA	9.2	6.7	11	6850	17	NA	169	0.12
GBN-2	6'	117627	1/24/99	7.8	1300	34	0.7	29	200	2060	2.35	2.52	1.82	0.7	17.19	9410	NA	<0.5	146	NA	21	0.8	NA	10	6.9	8.4	8160	7.5	NA	184	<0.1
GBN-3	6'	117628	1/24/99	5.6	6200	52	1.5	1.5	3000	52000	<1.78	1.88	1.88	<0.66	4.37	4350	NA	<0.5	108	NA	17	0.92	NA	7.5	4.4	21	7.21	10	NA	56	0.13
GBN-5	6'	120222	3/3/99	NA	NA	NA	NA	NA	NA	<10	NA	NA	NA	NA	NA	11300	NA	2	173	NA	53	<0.1	NA	9	2.7	5.1	9600	6.4	NA	180	0.14
GBN-6	6'	120223	3/3/99	NA	NA	NA	NA	NA	NA	87.8	NA	NA	NA	NA	NA	11200	NA	2	127	NA	50	<0.1	NA	8.1	2.8	5.1	9300	4.5	NA	147	<0.1
GBN-7	6'	120224	3/3/99	NA	NA	NA	NA	NA	NA	<10	NA	NA	NA	NA	NA	12400	NA	1.3	209	NA	60	<0.1	NA	10	3.1	7.9	11000	15	NA	257	0.11
GBN Maxiumum				**7.8**	**6200**	**52**	**1.5**	**29**	**3000**	**52000**	**2.35**	**2.91**	**2.25**	**0.7**	**17.19**	**12400**	**NA**	**2**	**209**	**NA**	**60**	**1.5**	**NA**	**10**	**6.9**	**21**	**11000**	**17**	**NA**	**257**	**0.14**
GBN Average				**7**	**2933.33**	**45**	**0.92**	**14.17**	**1113.33**	**15679.45**	**2.35**	**2.44**	**1.98**	**0.68**	**9.96**	**9321.67**	**NA**	**1.77**	**161.5**	**NA**	**37.67**	**1.07**	**NA**	**8.97**	**4.43**	**9.75**	**7486.20**	**10.07**	**NA**	**165.5**	**0.125**
GBN Minimum				**5.6**	**1300**	**34**	**0.56**	**1.5**	**140**	**87.8**	**2.35**	**1.88**	**1.82**	**0.66**	**4.37**	**4350**	**NA**	**1.3**	**108**	**NA**	**17**	**0.8**	**NA**	**7.5**	**2.7**	**5.1**	**7.21**	**4.5**	**NA**	**56**	**0.11**
GBS-1	6'	117629	1/24/99	NA	NA	11	NA	NA	NA	11000	NA	NA	NA	NA	NA	7130	NA	<0.5	152	NA	17	0.81	NA	8.8	6.2	8	6380	8.6	NA	164	<0.1
GBS-2	6'	117630	1/24/99	NA	NA	87	NA	NA	NA	25800	NA	NA	NA	NA	NA	6890	NA	<0.5	143	NA	15	0.83	NA	8.7	6.4	8.2	6000	8.5	NA	133	<0.1
GBS-3	6'	117631	1/24/99	NA	NA	12	NA	NA	NA	4360	NA	NA	NA	NA	NA	11100	NA	<0.5	144	NA	26	1.2	NA	14	9.7	11	9370	12	NA	232	<0.1
GBS-4	6'	120225	3/3/99	NA	NA	NA	NA	NA	NA	730	NA	NA	NA	NA	NA	9240	NA	1.8	154	NA	44	<0.1	NA	7	2.7	4.5	7960	4.8	NA	155	<0.1
GBS-5	6'	120226	3/3/99	NA	NA	NA	NA	NA	NA	419	NA	NA	NA	NA	NA	10400	NA	1.6	144	NA	47	<0.1	NA	7.6	2.9	4.8	8850	4.4	NA	159	<0.1
GBS-6	6'	120227	3/3/99	NA	NA	NA	NA	NA	NA	<10	NA	NA	NA	NA	NA	12000	NA	1.6	113	NA	54	<0.1	NA	9.5	2.9	6.4	10300	8.6	NA	209	<0.1
GBS Maxiumum				**NA**	**NA**	**87**	**NA**	**NA**	**NA**	**25800**	**NA**	**NA**	**NA**	**NA**	**NA**	**12000**	**NA**	**1.8**	**154**	**NA**	**54**	**1.2**	**0**	**14**	**9.7**	**11**	**10300**	**12**	**NA**	**232**	**ND**
GBS Average				**NA**	**NA**	**36.67**	**NA**	**NA**	**NA**	**8461.8**	**NA**	**NA**	**NA**	**NA**	**NA**	**9460**	**NA**	**1.67**	**141.67**	**NA**	**33.83**	**0.95**	**0**	**9.27**	**5.13**	**7.15**	**8143.33**	**7.82**	**NA**	**175.33**	**ND**
GBS Minimum				**NA**	**NA**	**11**	**NA**	**NA**	**NA**	**419**	**NA**	**NA**	**NA**	**NA**	**NA**	**6890**	**NA**	**1.6**	**113**	**NA**	**15**	**0.81**	**0**	**7**	**2.7**	**4.5**	**6000**	**4.4**	**NA**	**133**	**ND**
GMW-02	3'	106823	5/20/99	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	3160	NA	2.7	514	NA	<10	0.19	NA	3	6.3	1.5	2010	0.91	NA	16	NA
GSB-12	18-20'	118049	2/1/99	NA	NA	NA	NA	NA	NA	<10	NA	NA	NA	NA	NA	3100	NA	<0.5	220	NA	<10	0.38	NA	3.2	3.7	4.4	1890	4.2	NA	34	NA
GSB-12	8-10'	118048	2/1/99	NA	NA	NA	NA	NA	NA	<10	NA	NA	NA	NA	NA	2960	NA	<0.5	602	NA	13	0.42	NA	3.2	4.4	3.9	<2	0.71	NA	15	NA
GSB-13	18-20'	118050	2/1/99	NA	NA	NA	NA	NA	NA	<10	NA	NA	NA	NA	NA	3620	NA	<0.5	25	NA	<10	0.34	NA	4.9	3.3	7.1	2580	<0.5	NA	40	NA
GSB-14	18-20'	118052	2/1/99	NA	NA	NA	NA	NA	NA	<10	NA	NA	NA	NA	NA	3240	NA	<0.5	221	NA	11	0.28	NA	4	3.6	4.3	2150	0.98	NA	25	NA
GSB-14	8-10'	118051	2/1/99	NA	NA	NA	NA	NA	NA	<10	NA	NA	NA	NA	NA	4830	NA	<0.5	293	NA	19	0.28	NA	4.8	3.5	3.3	2830	<0.5	NA	21	NA
GSB-15	19-21'	T118242	2/1/99	NA	NA	NA	NA	NA	NA	<10	NA	NA	NA	NA	NA	990	NA	<0.5	1020	NA	<10	0.37	NA	2.7	3.6	5.5	694	<0.5	NA	9.9	NA
GSB-15	8-10'	T118241	2/1/99	NA	NA	NA	NA	NA	NA	<10	NA	NA	NA	NA	NA	3650	NA	<0.5	480	NA	16	0.35	NA	4.1	4.3	5.9	2200	<0.5	NA	23	NA
GSB-16	38-40'	118543	2/8/99	8.3	540	17	2.4	4.8	170	665	NA	1.86	NA	NA	NA	2750	NA	1.7	172	NA	14	<0.1	NA	2.9	0.61	1.6	2035	2	NA	22	<0.1
GSB-16	38-40'	118544	2/8/99	9.2	190	12	1.6	1.9	30	<10	NA	<2.3	NA	NA	NA	1813	NA	1	18	NA	<10	<0.1	NA	3.5	<0.5	<1	2291	2	NA	26	<0.1
GSB-17	3-5'	118541	2/8/99	8.6	360	34	4	1.4	61	<10	NA	2.85	NA	NA	NA	3895	NA	4.9	154	NA	22	<0.1	NA	3.7	<0.5	1.5	2443	2.6	NA	18	<0.1
GSB-17	38-40'	118542	2/8/99	8.9	760	140	1.1	1.9	270	<10	NA	11.03	NA	NA	NA	2072	NA	<0.5	6.5	NA	20	<0.1	NA	5.4	<0.5	1.5	2420	<0.5	NA	18	<0.1
GSB-18	4-5'	119264	2/18/99	NA	NA	NA	NA	NA	NA	<0.5	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
GSB Maxiumum				**9.2**	**760**	**140**	**4**	**4.8**	**270**	**665**	**NA**	**11.03**	**NA**	**NA**	**NA**	**4830**	**NA**	**4.9**	**1020**	**NA**	**22**	**0.42**	**NA**	**5.4**	**4.4**	**7.1**	**2830**	**4.2**	**NA**	**40**	**ND**
GSB Average				**8.75**	**462.5**	**50.75**	**2.275**	**2.5**	**132.75**	**665**	**NA**	**5.25**	**NA**	**NA**	**NA**	**2992.73**	**NA**	**2.53**	**291.95**	**NA**	**16.43**	**0.35**	**NA**	**3.85**	**3.38**	**3.9**	**2153.3**	**2.08**	**NA**	**22.9**	**ND**
GSB Minimum				**8.3**	**190**	**12**	**1.1**	**1.4**	**30**	**665**	**NA**	**1.86**	**NA**	**NA**	**NA**	**990**	**NA**	**1**	**6.5**	**NA**	**11**	**0.28**	**NA**	**2.7**	**0.61**	**1.5**	**694**	**0.71**	**NA**	**9.9**	**ND**

TABLE 4
1999 Soil Sample Detections
Hobbs, New Mexico

				E 150.1	E 160.1	E 300.0				E 418.1	E 901.1M					S 6010B															
Site Name	Sample Depth	Sample ID	Sample Date	pH	TDS	Chloride	Fluoride	Nitrate	Sulfate	TRPHC	Lead	Radium, Total	Radium-226	Radium-228	Total Activity	Aluminum	Antimony	Arsenic	Barium	Beryllium	Boron	Cadmium	Calcium	Chromium	Cobalt	Copper	Iron	Lead	Magnesium	Manganese	Mercury, Total
			Unit		*mg/Kg*	*mg/Kg*	*mg/Kg*	*mg/Kg*	*mg/Kg*	*mg/Kg*	*pCi/gm*	*pCi/gm*	*pCi/gm*	*pCi/gm*	*pCi/gm*	*mg/Kg*	*mg/Kg*	*mg/Kg*	*mg/Kg*	*mg/Kg*	*mg/Kg*	*mg/Kg*	*mg/Kg*	*mg/Kg*	*mg/Kg*	*mg/Kg*	*mg/Kg*	*mg/Kg*	*mg/Kg*	*mg/Kg*	*mg/Kg*
TSB-15	13-15'	T118243	2/5/99	NA	NA	NA	NA	NA	NA	<10	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
TSB-15	23-25'	T118244	2/5/99	NA	NA	NA	NA	NA	NA	<10	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
TSB-16	18-20'	118710	2/13/99	8.9	192	15	2.6	<0.2	7.7	17200	NA	2.49	NA	NA	NA	3332	NA	<0.5	130	NA	<10	0.43	NA	3.7	<0.5	4.1	2316	0.85	NA	29	<0.25
TSB-16	63-65'	118711	2/13/99	9.1	500	22	1.5	<0.2	9.4	51.7	NA	2.09	NA	NA	NA	1753	NA	<0.5	12	NA	<10	0.19	NA	2.6	<0.5	1.6	2126	1.2	NA	32	<0.1
TSB-16D	63-65'	118712	2/13/99	9.1	380	18	1.4	<0.2	6.7	<10	NA	1.68	NA	NA	NA	1683	NA	<0.5	12	NA	<10	0.29	NA	3	<0.5	2.2	1964	1.4	NA	31	<0.1
TSB-17	13-15'	119130	2/23/99	8.4	830	140	6.1	4.4	240	<10	NA	3.21	NA	NA	NA	9900	NA	<0.5	130	NA	78	<0.1	NA	<0.5	<0.5	2.4	5930	<0.5	NA	40	0.17
TSB-17	40-42'	119131	2/23/99	8.5	370	100	2.1	1.6	84	<10	NA	0.2	NA	NA	NA	2470	NA	<0.5	<0.5	NA	24	<0.1	NA	<0.5	<0.5	<1	2470	<0.5	NA	8.5	0.17
TSB-18	33-35'	119627	3/3/99	8.7	240	12	2.1	2.1	50	<10	NA	0.21	NA	NA	NA	2170	NA	<0.5	7.6	NA	14	<0.1	NA	2.1	<0.5	<1	2100	1.6	NA	15	0.11
TSB-18	43-45'	119628	3/3/99	8.8	265	10	1.4	1.9	38	<10	NA	1.7	NA	NA	NA	1960	NA	<0.5	5.5	NA	15	<0.1	NA	1.7	<0.5	<1	2180	1.2	NA	16	0.1
TSB-19	38-40'	119630	3/3/99	8.7	220	31	1.3	1.5	22	<10	NA	5.65	NA	NA	NA	2700	NA	<0.5	7.9	NA	15	<0.1	NA	1.6	<0.5	<1	2830	0.52	NA	17	0.1
TSB-19	8-10'	119629	3/3/99	8	4400	1100	1.4	6.1	1900	<10	NA	2.02	NA	NA	NA	2730	NA	5.5	304	NA	16	<0.1	NA	<0.5	<0.5	1.9	1550	1.5	NA	11	0.1
TSB-23	38-40'	905078-01	5/20/99	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
TSB-23	38-40'	992198-1	5/20/99	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	4540	<15	<25	131	<1	<25	<1.5	50900	4.2	<2.5	4.7	4570	<15	1970	139	NA
TSB-23	38-40'	T125255	5/20/99	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
TSB-23	6-8'	T125255b	5/20/99	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	6460	NA	2.2	103	NA	33	<0.5	NA	5.4	1.8	5.2	5210	5.8	NA	145	NA
TSB-27	6-8'	T125256	5/20/99	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	4340	NA	2.3	88	NA	29	<0.5	NA	4.7	1.8	5.1	3480	4.8	NA	155	NA
TSB-32	6-8'	905078-02	5/20/99	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
TSB-32	6-8'	9905118-02A	5/20/99	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
TSB-32	6-8'	992198-2	5/20/99	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	4050	<3	<5	108	0.4	<5	<0.3	30200	5.9	2.6	10	4710	7	1710	122	NA
TSB-32	6-8'	T125257	5/20/99	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	6580	NA	1.9	109	NA	30	<0.5	NA	5	1.7	7.5	5330	7.8	NA	147	NA
TSB-39	6-8'	T125258	5/20/99	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	4490	NA	1.8	102	NA	24	<0.5	NA	4	1.8	5.7	3570	5.2	NA	162	NA
TSB-42	6-8'	T125259	5/20/99	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	5520	NA	1.7	99	NA	30	<0.5	NA	5.1	1.7	5.7	4580	6.9	NA	148	NA
TSB-49	6-8'	905078-03	5/20/99	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
TSB-49	6-8'	9905118-03A	5/20/99	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
TSB-49	6-8'	992198-3	5/20/99	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	4190	5	<5	105	0.4	<5	<0.3	34600	4.3	2.6	5.1	4100	5	2020	143	NA
TSB-49	6-8'	T125260	5/20/99	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	4510	NA	1.2	109	NA	25	<0.5	NA	3.8	1.4	5.5	3820	4.6	NA	145	NA
TSB Maxiumum				**9.1**	**4400**	**1100**	**6.1**	**6.1**	**1900**	**17200**	**NA**	**5.65**	**NA**	**NA**	**NA**	**9900**	**5**	**5.5**	**304**	**0.4**	**78**	**0.43**	**50900**	**5.9**	**2.6**	**10**	**5930**	**7.8**	**2020**	**162**	**0.17**
TSB Average				**8.69**	**821.89**	**160.89**	**2.21**	**2.93**	**261.98**	**8625.85**	**NA**	**2.14**	**NA**	**NA**	**NA**	**4076.56**	**5**	**2.37**	**91.94**	**0.4**	**27.75**	**0.30**	**38567**	**3.81**	**1.93**	**4.76**	**3490.89**	**3.69**	**1900**	**83.64**	**0.125**
TSB Minimum				**8**	**192**	**10**	**1.3**	**1.5**	**6.7**	**51.7**	**NA**	**0.2**	**NA**	**NA**	**NA**	**1683**	**5**	**1.2**	**5.5**	**0.4**	**14**	**0.19**	**30200**	**1.6**	**1.4**	**1.6**	**1550**	**0.52**	**1710**	**8.5**	**0.1**

NOTES:

NA = Sample not analyzed for this constituent.

ND = Constituent not detected at method detection limit.

TABLE 4
1999 Soil Sample Detections
Hobbs, New Mexico

				S 6010B							S 7841	S 8080	S 8260B					S 8270										SM 5530 A,D
Site Name	Sample Depth	Sample ID	Sample Date	Molybdenum	Nickel	Potassium	Silicon	Silver	Vanadium	Zinc	Sodium	Solids, Percent	Ethylbenzene	m,p-xylene	Naphthalene	o-xylene	Toluene	1-Methylnaphthalene	2-Methylnaphthalene	Acenaphthylene	Benzo(a)anthracene	Benzo(a)pyrene	Benzo(b)fluoranthene	Benzo(k)fluoranthene	Chrysene	Fluorene	Phenanthrene	Phenols, Total
			Unit	mg/Kg	mg/Kg	mg/Kg	mg/Kg	mg/Kg	mg/Kg	mg/Kg	mg/Kg	mg/Kg	mg/Kg	mg/Kg	mg/Kg	mg/Kg	mg/Kg	mg/Kg	mg/Kg	mg/Kg	mg/Kg	mg/Kg	mg/Kg	mg/Kg	mg/Kg	mg/Kg	mg/Kg	mg/Kg
Maximum of All Samples				**3.8**	**38**	**1880**	**2090**	**30**	**10.3**	**76**	**194**	**96.7**	**88**	**390**	**7**	**105**	**0.065**	**17**	**19**	**109**	**7.5**	**1.7**	**27**	**30**	**147**	**5**	**7.8**	**5.59**
Average of All Samples				**2.22**	**14.62**	**1585**	**1536.67**	**16.59**	**9.27**	**18.55**	**152.5**	**92.19**	**46.95**	**205**	**4.45**	**105**	**0.065**	**17**	**19**	**109**	**7.5**	**1.7**	**27**	**30**	**147**	**5**	**5.75**	**1.88**
Minimum of All Samples				**1.3**	**0.93**	**1290**	**1120**	**0.8**	**7.6**	**3.8**	**111**	**85.5**	**5.9**	**20**	**1.9**	**105**	**0.065**	**17**	**19**	**109**	**7.5**	**1.7**	**27**	**30**	**147**	**5**	**3.7**	**0.609**
GBN-1	6'	117626	1/24/99	2.5	21	NA	NA	25	NA	76	NA	92.6	<0.034	<0.034	NA	<0.034	<0.034	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	1.66
GBN-2	6'	117627	1/24/99	2.5	22	NA	NA	29	NA	35	NA	92.6	<0.025	<0.025	NA	<0.025	<0.025	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	5.59
GBN-3	6'	117628	1/24/99	2.7	34	NA	NA	30	NA	35	NA	NA	<0.026	<0.026	NA	<0.026	<0.026	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	3.7
GBN-5	6'	120222	3/3/99	<1	10	NA	NA	<0.5	NA	30	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	<0.5
GBN-6	6'	120223	3/3/99	<1	10	NA	NA	<0.5	NA	27	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	<0.5
GBN-7	6'	120224	3/3/99	<1	12	NA	NA	<0.5	NA	73	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	<0.5
GBN Maxiumum				**2.7**	**34**	**NA**	**NA**	**30**	**NA**	**76**	**NA**	**92.6**	**ND**	**ND**	**NA**	**ND**	**ND**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**5.59**
GBN Average				**2.57**	**18.17**	**NA**	**NA**	**28**	**NA**	**46**	**NA**	**92.6**	**ND**	**ND**	**NA**	**ND**	**ND**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**3.65**
GBN Minimum				**2.5**	**10**	**NA**	**NA**	**25**	**NA**	**27**	**NA**	**92.6**	**ND**	**ND**	**NA**	**ND**	**ND**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**1.66**
GBS-1	6'	117629	1/24/99	2.5	31	NA	NA	25	NA	28	NA	NA	<0.027	<0.027	NA	<0.027	<0.027	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
GBS-2	6'	117630	1/24/99	2.6	30	NA	NA	25	NA	28	NA	NA	<0.027	<0.027	NA	<0.027	<0.027	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
GBS-3	6'	117631	1/24/99	3.8	38	NA	NA	30	NA	42	NA	NA	<0.025	<0.025	NA	<0.025	<0.025	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
GBS-4	6'	120225	3/3/99	<1	9.7	NA	NA	<0.5	NA	24	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
GBS-5	6'	120226	3/3/99	<1	10	NA	NA	<0.5	NA	25	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
GBS-6	6'	120227	3/3/99	<1	11	NA	NA	<0.5	NA	30	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
GBS Maxiumum				**3.8**	**38**	**NA**	**NA**	**30**	**NA**	**42**	**NA**	**NA**	**ND**	**ND**	**NA**	**ND**	**ND**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**
GBS Average				**2.97**	**21.62**	**NA**	**NA**	**26.67**	**NA**	**29.5**	**NA**	**NA**	**ND**	**ND**	**NA**	**ND**	**ND**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**
GBS Minimum				**2.5**	**9.7**	**NA**	**NA**	**25**	**NA**	**24**	**NA**	**NA**	**ND**	**ND**	**NA**	**ND**	**ND**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**
GMW-02	3'	106823	5/20/99	1.3	6.8	NA	NA	<0.5	NA	6.6	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
GSB-12	18-20'	118049	2/1/99	1.9	18	NA	NA	13	NA	5.8	NA	NA	<26	<26	NA	<26	<26	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
GSB-12	8-10'	118048	2/1/99	1.5	27	NA	NA	7.8	NA	5.4	NA	NA	<26	<26	NA	<26	<26	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
GSB-13	18-20'	118050	2/1/99	2	14	NA	NA	17	NA	8	NA	NA	<25	<25	NA	<25	<25	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
GSB-14	18-20'	118052	2/1/99	1.7	23	NA	NA	14	NA	6	NA	NA	<27	<27	NA	<27	<27	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
GSB-14	8-10'	118051	2/1/99	2.4	17	NA	NA	15	NA	8.3	NA	NA	<37	<37	NA	<37	<37	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
GSB-15	19-21'	T118242	2/1/99	1.6	38	NA	NA	6.3	NA	7	NA	NA	<26	<26	NA	<26	<26	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
GSB-15	8-10'	T118241	2/1/99	2.5	26	NA	NA	13	NA	10	NA	NA	<29	<29	NA	<29	<29	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
GSB-16	38-40'	118543	2/8/99	<1	2.8	NA	NA	<0.5	NA	6.6	NA	96.1	<29	<29	<2.5	<29	<29	<2.5	<2.5	NA	NA	<2.5	NA	<2.5	NA	<2.5	<2.5	0.679
GSB-16	38-40'	118544	2/8/99	<1	<0.5	NA	NA	<0.5	NA	4.6	NA	95.1	88	390	<0.25	105	<27	<0.25	<0.25	NA	NA	<0.25	NA	<0.25	NA	<0.25	<0.25	1.44
GSB-17	3-5'	118541	2/8/99	<1	3	NA	NA	<0.5	NA	6.7	NA	93.4	<27	<27	<0.25	<27	<27	<0.25	<0.25	NA	NA	<0.25	NA	<0.25	NA	<0.25	<0.25	<0.5
GSB-17	38-40'	118542	2/8/99	<1	<0.5	NA	NA	<0.5	NA	5.6	NA	93.8	<29	<29	<0.25	<29	<29	<0.25	<0.25	NA	NA	<0.25	NA	<0.25	NA	<0.25	<0.25	<0.5
GSB-18	4-5'	119264	2/18/99	NA	NA	NA	NA	NA	NA	NA	NA	NA	<26	<26	NA	<26	<26	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
GSB Maxiumum				**2.5**	**38**	**NA**	**NA**	**17**	**NA**	**10**	**NA**	**96.1**	**88**	**390**	**ND**	**105**	**ND**	**ND**	**ND**	**NA**	**NA**	**ND**	**NA**	**ND**	**NA**	**ND**	**ND**	**1.44**
GSB Average				**1.94**	**18.76**	**NA**	**NA**	**12.3**	**NA**	**6.73**	**NA**	**94.6**	**88**	**390**	**ND**	**105**	**ND**	**ND**	**ND**	**NA**	**NA**	**ND**	**NA**	**ND**	**NA**	**ND**	**ND**	**1.06**
GSB Minimum				**1.5**	**2.8**	**NA**	**NA**	**6.3**	**NA**	**4.6**	**NA**	**93.4**	**88**	**390**	**ND**	**105**	**ND**	**ND**	**ND**	**NA**	**NA**	**ND**	**NA**	**ND**	**NA**	**ND**	**ND**	**0.68**

TABLE 4
1999 Soil Sample Detections
Hobbs, New Mexico

				S 6010B							S 7841	S 8080	S 8260B					S 8270										SM 5530 A,D
Site Name	Sample Depth	Sample ID	Sample Date	Molybdenum	Nickel	Potassium	Silicon	Silver	Vanadium	Zinc	Sodium	Solids, Percent	Ethylbenzene	m,p-xylene	Naphthalene	o-xylene	Toluene	1-Methylnaphthalene	2-Methylnaphthalene	Acenaphthylene	Benzo(a)anthracene	Benzo(a)pyrene	Benzo(b)fluoranthene	Benzo(k)fluoranthene	Chrysene	Fluorene	Phenanthrene	Phenols, Total
			Unit	mg/Kg	mg/Kg	mg/Kg	mg/Kg	mg/Kg	mg/Kg	mg/Kg	mg/Kg	mg/Kg	mg/Kg	mg/Kg	mg/Kg	mg/Kg	mg/Kg	mg/Kg	mg/Kg	mg/Kg	mg/Kg	mg/Kg	mg/Kg	mg/Kg	mg/Kg	mg/Kg	mg/Kg	mg/Kg
TSB-15	13-15'	T118243	2/5/99	NA	NA	NA	NA	NA	NA	NA	NA	NA	<0.026	<0.026	NA	<0.026	<26	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
TSB-15	23-25'	T118244	2/5/99	NA	NA	NA	NA	NA	NA	NA	NA	NA	<0.026	<0.026	NA	<0.026	<26	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
TSB-16	18-20'	118710	2/13/99	1.8	36	NA	NA	16	NA	5.2	NA	85.5	5.9	20	7	<0.1	<0.1	17	19	NA	NA	<1.5	NA	<1.5	NA	<1.5	3.7	<0.5
TSB-16	63-65'	118711	2/13/99	<1	22	NA	NA	8	NA	4.3	NA	93.4	<0.025	<0.025	<0.25	<0.025	0.065	<0.25	<0.25	NA	NA	<0.25	NA	<0.25	NA	<0.25	<0.25	<0.5
TSB-16D	63-65'	118712	2/13/99	<1	14	NA	NA	7.1	NA	4.1	NA	92.3	<0.025	<0.025	<0.25	<0.025	<0.025	<0.25	<0.25	NA	NA	<0.25	NA	<0.25	NA	<0.25	<0.25	0.609
TSB-17	13-15'	119130	2/23/99	<1	9	NA	NA	<0.5	NA	21	NA	90.2	<0.026	<0.026	<0.25	<0.026	<0.026	<0.25	<0.25	NA	NA	<0.25	NA	<0.25	NA	<0.25	<0.25	<0.5
TSB-17	40-42'	119131	2/23/99	<1	<0.5	NA	NA	<0.5	NA	3.8	NA	95.2	<0.025	<0.025	<0.25	<0.025	<0.025	<0.25	<0.25	NA	NA	<0.25	NA	<0.25	NA	<0.25	<0.25	0.627
TSB-18	33-35'	119627	3/3/99	<1	1.3	NA	NA	<0.5	NA	5	NA	87.1	<0.026	<0.026	<0.25	<0.026	<0.026	<0.25	<0.25	NA	NA	<0.25	NA	<0.25	NA	<0.25	<0.25	<0.5
TSB-18	43-45'	119628	3/3/99	<1	0.93	NA	NA	<0.5	NA	6.5	NA	NA	<0.028	<0.028	<0.25	<0.028	<0.028	<0.25	<0.25	NA	NA	<0.25	NA	<0.25	NA	<0.25	<0.25	0.697
TSB-19	38-40'	119630	3/3/99	<1	1.4	NA	NA	<0.5	NA	5.4	NA	96.7	<0.026	<0.026	<0.25	<0.026	<0.026	<0.25	<0.25	NA	NA	<0.25	NA	<0.25	NA	<0.25	<0.25	<0.5
TSB-19	8-10'	119629	3/3/99	<1	3.2	NA	NA	<0.5	NA	4	NA	86.7	<0.026	<0.026	<0.25	<0.026	<0.026	<0.25	<0.25	NA	NA	<0.25	NA	<0.25	NA	<0.25	<0.25	<0.5
TSB-23	38-40'	905078-01	5/20/99	NA	NA	NA	NA	NA	NA	NA	NA	NA	<0.05	<0.05	<0.05	<0.05	<0.05	NA	<2.51	<2.51	<2.51	<2.51	<2.51	<2.51	<2.51	<2.51	<2.51	NA
TSB-23	38-40'	992198-1	5/20/99	<2.5	<10	<1500	2090	<2.5	9.9	15	<250	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
TSB-23	38-40'	T125255	5/20/99	NA	NA	NA	NA	NA	NA	NA	NA	NA	<0.025	<0.025	NA	<0.025	<0.025	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
TSB-23	6-8'	T125255b	5/20/99	<0.5	7.7	NA	NA	<0.5	NA	21	NA	NA	NA	NA	1.9	NA	NA	NA	NA	109	7.5	1.7	27	30	147	5	7.8	NA
TSB-27	6-8'	T125256	5/20/99	<0.5	6.9	NA	NA	<0.5	NA	18	NA	NA	<0.025	<0.025	<1.25	<0.025	<0.025	NA	NA	<1.25	<1.25	<1.25	<1.25	<1.25	<1.25	<1.25	<1.25	NA
TSB-32	6-8'	905078-02	5/20/99	NA	NA	NA	NA	NA	NA	NA	NA	NA	<0.05	<0.05	<0.05	<0.05	<0.05	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
TSB-32	6-8'	9905118-02A	5/20/99	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	<2.51	NA	NA	NA	<2.51	<2.51	<2.51	<2.51	<2.51	<2.51	<2.51	<2.51	<2.51	NA
TSB-32	6-8'	992198-2	5/20/99	<0.5	5	1290	1400	<0.5	7.6	30	194	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
TSB-32	6-8'	T125257	5/20/99	<0.5	6.5	NA	NA	<0.5	NA	27	NA	NA	<0.025	<0.025	<1.25	<0.025	<0.025	NA	NA	<1.25	<1.25	<1.25	<1.25	<1.25	<1.25	<1.25	<1.25	NA
TSB-39	6-8'	T125258	5/20/99	<0.5	7.2	NA	NA	<0.5	NA	16	NA	NA	<0.025	<0.025	<1.25	<0.025	<0.025	NA	NA	<1.25	<1.25	<1.25	<1.25	<1.25	<1.25	<1.25	<1.25	NA
TSB-42	6-8'	T125259	5/20/99	<0.5	6.4	NA	NA	<0.5	NA	24	NA	NA	<0.026	<0.026	NA	<0.026	<0.026	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
TSB-49	6-8'	905078-03	5/20/99	NA	NA	NA	NA	NA	NA	NA	NA	NA	<0.05	<0.05	<0.05	<0.05	<0.05	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
TSB-49	6-8'	9905118-03A	5/20/99	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	<2.51	NA	NA	NA	<2.51	<2.51	<2.51	<2.51	<2.51	<2.51	<2.51	<2.51	<2.51	NA
TSB-49	6-8'	992198-3	5/20/99	<0.5	7	1880	1120	0.8	10.3	16	111	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
TSB-49	6-8'	T125260	5/20/99	<0.5	6.9	NA	NA	<0.5	NA	19	NA	NA	<0.026	<0.026	<1.25	<0.026	<0.026	NA	NA	<1.25	<1.25	<1.25	<1.25	<1.25	<1.25	<1.25	<1.25	NA
			TSB Maxiumum	**1.8**	**36**	**1880**	**2090**	**16**	**10.3**	**30**	**194**	**96.7**	**5.9**	**20**	**7**	**ND**	**0.065**	**17**	**19**	**109**	**7.5**	**1.7**	**27**	**30**	**147**	**5**	**7.8**	**0.70**
			TSB Average	**1.8**	**8.84**	**1585**	**1536.67**	**7.975**	**9.27**	**13.63**	**152.5**	**90.89**	**5.9**	**20**	**4.45**	**ND**	**0.065**	**17**	**19**	**109**	**7.5**	**1.7**	**27**	**30**	**147**	**5**	**5.75**	**0.64**
			TSB Minimum	**1.8**	**0.93**	**1290**	**1120**	**0.8**	**7.6**	**3.8**	**111**	**85.5**	**5.9**	**20**	**1.9**	**ND**	**0.065**	**17**	**19**	**109**	**7.5**	**1.7**	**27**	**30**	**147**	**5**	**3.7**	**0.61**

NOTES:

NA = Sample not analyzed for this constituent.

ND = Constituent not detected at method detection limit.

TABLE 5
Groundwater Detections (μg/L)
Hobbs, New Mexico

Well	Sample Date	Benzene	Chrysene	Ethylbenzene	m,p-xylene	Naphthalene	o-xylene	Phenanthrene	Toluene
GMW-01									
	9/28/99	0.031	<0.005	0.18	0.47	0.098	0.25	<0.005	0.0093
	12/20/99	0.022	<0.005	0.113	0.565	0.034	0.169	<0.005	0.028
GMW-03b									
	9/28/99	0.0087	0.006	0.1	0.4	0.081	0.18	0.027	<0.005
	12/20/99	<0.01	<0.005	0.03	0.202	0.02	0.052	0.006	<0.01
GMW-05									
	9/28/99	<0.05	0.061	0.4	1.7	0.595	0.69	0.271	<0.05
	12/20/99	0.024	<0.025	0.254	1.969	0.138	0.458	0.042	0.027
GMW-08									
	9/24/99	<0.002	<0.005	<0.002	0.0023	<0.005	<0.002	<0.005	<0.002
	12/20/99	<0.002	<0.005	<0.002	0.0026	<0.005	<0.002	<0.005	<0.002
GMW-09									
	9/28/99	<0.005	0.005	0.06	0.11	0.035	0.075	0.017	<0.005
	12/20/99	<0.002	<0.005	0.02501	0.10256	0.008	0.03447	<0.005	<0.002
GMW-11									
	3/21/00	<0.002	NA	0.00328	<0.002	NA	<0.002	NA	<0.002
TMW-1									
	12/20/99	<0.002	<0.005	<0.002	<0.002	<0.005	<0.002	<0.005	<0.002
	3/21/00	<0.002	NA	0.00409	<0.002	NA	<0.002	NA	<0.002
TMW-2									
	3/21/00	<0.002	NA	0.00442	<0.002	NA	<0.002	NA	<0.002
TMW-3									
	3/21/00	<0.002	NA	0.03532	0.01997	NA	0.00876	NA	0.00995
	6/12/00	<0.002	NA	<0.002	<0.002	NA	<0.002	NA	<0.002
TMW-4									
	3/21/00	<0.002	NA	0.00638	<0.002	NA	<0.002	NA	<0.002
	6/12/00	<0.002	NA	<0.002	<0.002	NA	<0.002	NA	0.00392
TMW-5									
	9/24/99	<0.002	<0.005	0.03	<0.002	<0.005	<0.002	<0.005	<0.002
	12/20/99	<0.002	<0.005	0.01969	<0.002	<0.005	<0.002	<0.005	<0.002
	3/21/00	0.00214	NA	<0.002	<0.002	NA	0.00243	NA	0.111
	6/12/00	<0.002	NA	<0.002	0.00211	NA	<0.002	NA	0.0866
	9/21/00	<0.002	NA	<0.002	<0.002	NA	<0.002	NA	0.02278
	12/20/00	<0.002	<0.005	<0.002	<0.002	<0.005	<0.002	<0.005	0.0752
	9/26/01	0.00146	NA	<0.001	<0.001	NA	<0.001	NA	0.0803
	12/17/01	<0.001	<0.005	<0.001	<0.001	<0.005	<0.001	<0.005	0.0456

Notes:

Samples not listed contained no detections.

NA = Sample not analyzed for this constituent.

TABLE 6
Soil Gas Detections, May 1999
Westgate Subdivision, Hobbs, New Mexico

Well	Depth	Date	Butane mg/L	Carbon Dioxide %	Ethane mg/L	Hexane mg/L	Nitrogen %	Oxygen %	Propane mg/L	TPH mg/L	Xylenes, Total mg/L
Samples With TPH Detections											
SV-286	9.5	36297	ND	8	2	ND	76	8	ND	95	ND
SV-323	10	36299	ND	4.64	1	ND	26	2	ND	90	2
TN	5	36193	ND	NA	ND	ND	NA	NA	ND	41	ND
SV-317	10	36299	ND	8.62	ND	ND	81	10	ND	38	ND
SV-306	9	36299	ND	9	7	ND	80	7	2	16	ND
SV-250	10	36192	ND	NA	2	ND	NA	NA	ND	14	ND
SV-249	5	36192	ND	NA	ND	ND	NA	NA	ND	5	ND
SV-283	1	36297	ND	2.35	ND	ND	80	19	ND	4	ND
TN	10	36193	ND	NA	2	ND	NA	NA	ND	3	ND
SV-329	11	36300	ND	2.72	ND	ND	79	18	ND	2	ND
SV-298	5	36298	ND	1.5	ND	ND	79	20	ND	1	ND
SV-326	3	36300	ND	0.96	ND	ND	77	20	ND	1	ND
Samples With Detections Other Than TPH											
SV-314	3	36299	ND	0.6	ND	1	79	20	ND	ND	ND
SV-255	5	36192	1	NA	10	ND	NA	NA	5	ND	ND
SV-301	5	36298	ND	5.51	4	ND	79	20	2	ND	ND
SV-256	9	36192	ND	NA	3	ND	NA	NA	ND	ND	ND
SV-266	9	36193	ND	NA	3	ND	NA	NA	ND	ND	ND
SV-252	9	36192	ND	NA	3	ND	NA	NA	1	ND	ND
SV-251	5	36192	ND	NA	2	ND	NA	NA	ND	ND	ND
SV-253	5	36192	ND	NA	2	ND	NA	NA	ND	ND	ND
SV-268	10	36193	ND	NA	2	ND	NA	NA	ND	ND	ND
SV-291	10	36298	ND	7	2	ND	84	11	ND	ND	ND
SV-334	10	36300	ND	1.27	2	ND	82	18	ND	ND	ND
SV-338	10	36301	ND	0.26	2	ND	75	18	ND	ND	ND
SV-264	10	36193	ND	NA	1	ND	NA	NA	ND	ND	ND
SV-300	5	36298	ND	0.73	1	ND	79	20	ND	ND	ND
SV-343	10	36301	ND	0.96	1	ND	77	19	ND	ND	ND
SV-344	10	36301	ND	0.79	1	ND	76	20	ND	ND	ND
SV-273	1	36297	ND	0.59	ND	ND	80	20	ND	ND	ND
SV-275	5	36297	ND	1.76	ND	ND	75	19	ND	ND	ND
SV-276	10	36297	ND	2.33	ND	ND	77	19	ND	ND	ND
SV-277	5	36297	ND	2.78	ND	ND	76	19	ND	ND	ND
SV-278	1	36297	ND	1.67	ND	ND	75	19	ND	ND	ND
SV-279	3	36297	ND	3.29	ND	ND	76	18	ND	ND	ND
SV-280	5	36297	ND	4.32	ND	ND	77	17	ND	ND	ND
SV-281	10	36297	ND	5.11	ND	ND	82	13	ND	ND	ND
SV-282	5.5	36297	ND	4.92	ND	ND	77	16	ND	ND	ND
SV-284	3	36297	ND	4.84	ND	ND	80	15	ND	ND	ND
SV-285	5	36297	ND	1.2	ND	ND	79	20	ND	ND	ND
SV-287	5	36297	ND	3.2	ND	ND	7.8	17	ND	ND	ND
SV-288	1	36298	ND	0.9	ND	ND	76	20	ND	ND	ND
SV-289	3	36298	ND	0.9	ND	ND	76	20	ND	ND	ND
SV-290	5	36298	ND	6	ND	ND	79	14	ND	ND	ND
SV-292	5	36298	ND	6	ND	ND	82	14	ND	ND	ND
SV-293	5	36298	ND	0.8	ND	ND	77	21	ND	ND	ND
SV-294	5	36298	ND	1	ND	ND	71	19	ND	ND	ND
SV-295	5	36298	ND	2	ND	ND	79	19	ND	ND	ND
SV-296	5	36298	ND	1.15	ND	ND	79	19	ND	ND	ND
SV-297	5	36298	ND	3.1	ND	ND	80	18	ND	ND	ND
SV-299	5	36298	ND	5.51	ND	ND	78	15	ND	ND	ND
SV-302	5	36298	ND	8	ND	ND	80	12	ND	ND	ND
SV-303	5	36299	ND	1.2	ND	ND	78	20	ND	ND	ND

TABLE 6
Soil Gas Detections, May 1999
Westgate Subdivision, Hobbs, New Mexico

Well	Depth	Date	Butane	Carbon Dioxide	Ethane	Hexane	Nitrogen	Oxygen	Propane	TPH	Xylenes, Total
SV-304	3	36299	ND	2	ND	ND	77	18	ND	ND	ND
SV-305	5	36299	ND	7	ND	ND	82	14	ND	ND	ND
SV-307	5.5	36299	ND	7	ND	ND	80	13	ND	ND	ND
SV-308	1	36300	ND	2.28	ND	ND	76	20	ND	ND	ND
SV-309	3	36300	ND	2	ND	ND	75	19	ND	ND	ND
SV-310	5	36300	ND	1.73	ND	ND	74	19	ND	ND	ND
SV-311	10	36300	ND	1.32	ND	ND	78	19	ND	ND	ND
SV-312	7	36300	ND	3.17	ND	ND	78	18	ND	ND	ND
SV-313	1	36299	ND	1.2	ND	ND	79	18	ND	ND	ND
SV-315	5	36299	ND	6.84	ND	ND	81	14	ND	ND	ND
SV-316	7.5	36299	ND	4.65	ND	ND	78	15	ND	ND	ND
SV-318	6.5	36299	ND	0.36	ND	ND	76	20	ND	ND	ND
SV-319	1	36299	ND	1.27	ND	ND	78	19	ND	ND	ND
SV-320	3	36299	ND	4.86	ND	ND	62	12	ND	ND	ND
SV-321	5	36299	ND	7.86	ND	ND	79	12	ND	ND	ND
SV-322	7.5	36299	ND	9.48	ND	ND	77	10	ND	ND	ND
SV-324	7	36299	ND	7	ND	ND	80	13	ND	ND	ND
SV-325	1	36300	ND	0.15	ND	ND	73	20	ND	ND	ND
SV-327	5	36300	ND	2	ND	ND	73	18	ND	ND	ND
SV-328	10	36300	ND	3.73	ND	ND	70	15	ND	ND	ND
SV-330	1	36300	ND	1.19	ND	ND	80	18	ND	ND	ND
SV-331	3	36300	ND	2	ND	ND	76	18	ND	ND	ND
SV-332	5	36300	ND	2.07	ND	ND	80	18	ND	ND	ND
SV-333	10	36300	ND	2.03	ND	ND	80	18	ND	ND	ND
SV-335	1	36301	ND	0.53	ND	ND	76	19	ND	ND	ND
SV-336	3	36301	ND	1.01	ND	ND	70	17.2	ND	ND	ND
SV-337	5	36301	ND	1.33	ND	ND	79	19	ND	ND	ND
SV-339	10	36301	ND	0.9	ND	ND	79	20	ND	ND	ND
SV-340	1	36301	ND	1.02	ND	ND	80	20	ND	ND	ND
SV-341	3	36301	ND	0.27	ND	ND	79	21	ND	ND	ND
SV-342	5	36301	ND	1.92	ND	ND	79	19	ND	ND	ND

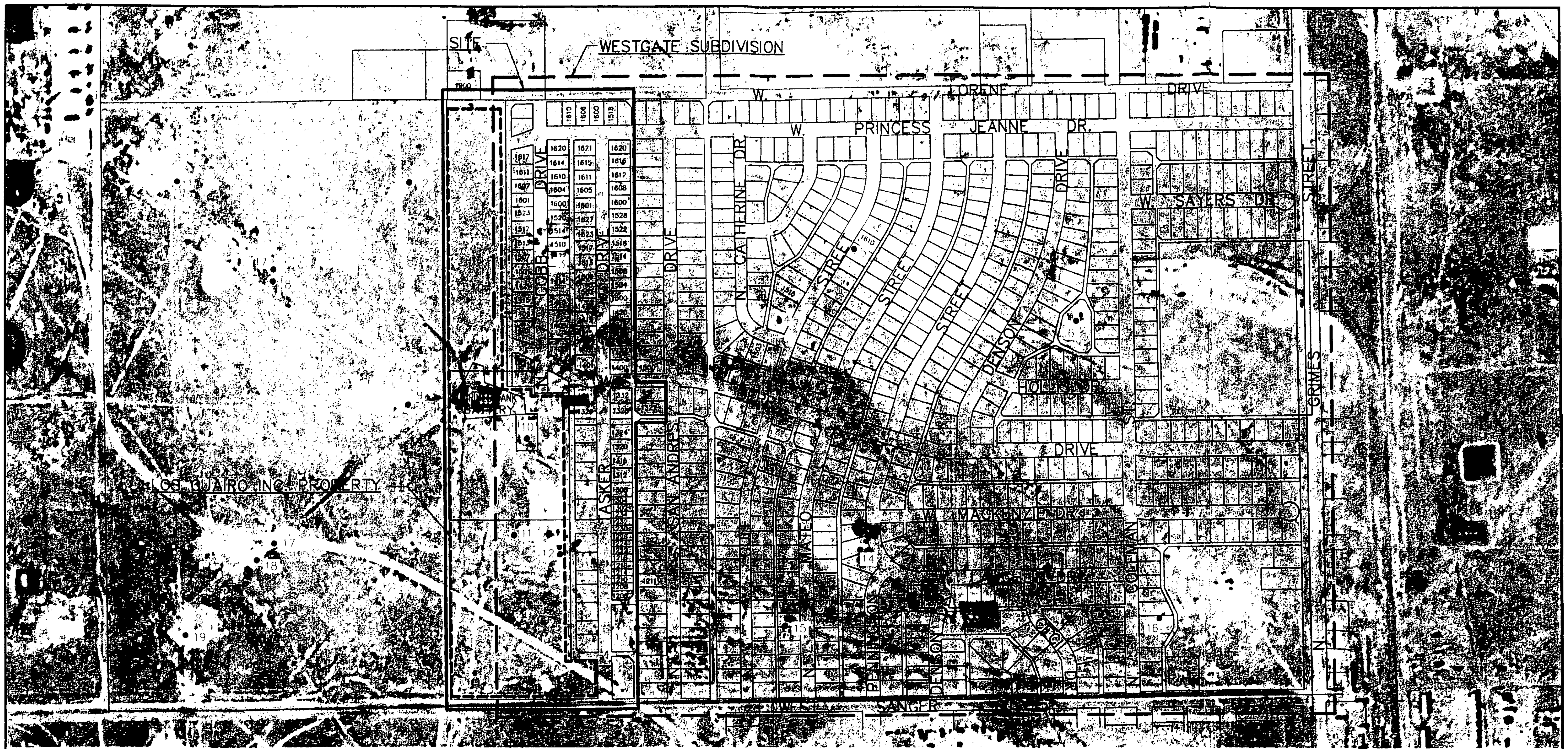
Notes:

Samples not listed contained no detections.

NA = Sample not analyzed for this constituent.

ND = Constituent not detected at method detection limit.

FIGURES



No.	WELL No	WELL NAME	TYPE
1	131	ALTURA ENERGY LTD., GSA	P
2	232	ALTURA ENERGY LTD., GSA	INJ
3	8	SHELL OIL CO. W.D. GRIMES	P&A
4	331	ALTURA ENERGY LTD., GSA	INJ
5	6	* CONOCO, INC. W.D. GRIMES	P&A
6	431	ALTURAL ENERGY LTD., GSA	INJ
7	5	SHELL OIL CO. W.D. GRIMES	P&A
8	132	ALTURA ENERGY LTD., GSA	P
9	231	ALTURA ENERGY LTD., GSA	INJ

No.	WELL No.	WELL NAME	TYPE
10	242	ALTURA ENERGY LTD., GSA	INJ
11	243	ALTURA ENERGY LTD., GSA	INJ
12	7	SHELL OIL CO. W.D. GRIMES	P&A
13	241	ALTURA ENERGY LTD., GSA	INJ
14	341	ALTURA ENERGY LTD.,	INJ
15	5	* CONOCO, INC. W.D. GRIMES	P&A
16	441	ALTURA ENERGY LTD., GSA	INJ
17	142	ALTURA ENERGY LTD., GSA	INJ
18	6	SHELL OIL CO. W.D. GRIMES	P&A
19	141	ALTURA ENERGY LTD., GSA	P

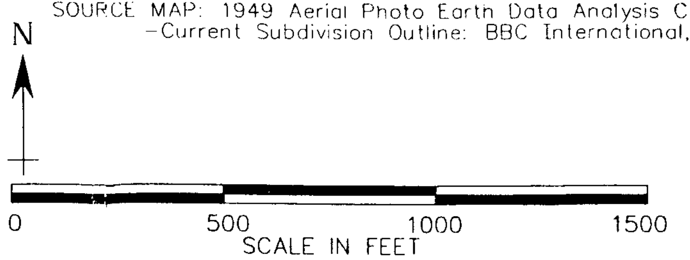
EXPLANATION

1. INJ – DENOTES INJECTION WELL
2. P – DENOTES PRODUCTION WELL
3. P&A – DENOTES PLUGGED & ABANDONED WELL

* – DENOTES ACTUAL WELL LOCATION NOT FOUND
(NMOCD CALLS USED)

— — WESTGATE SUBDIVISION
—— SITE
– – – – LOS CUAIRO INC. PROPERTY

SOURCE MAP: 1949 Aerial Photo Earth Data Analysis Center
–Current Subdivision Outline: BBC International, Inc.



HYDRO
GEO
CHEM, INC.

CURRENT ACTIVE AND INACTIVE OIL WELL LOCATIONS
1949 LAND SURFACE WITH CURRENT SUBDIVISION OVERLAY
HOBBS, NEW MEXICO

Approved	Date	Revised	Date	Reference:	FIG.
JM	02/13/03			7850003A	1

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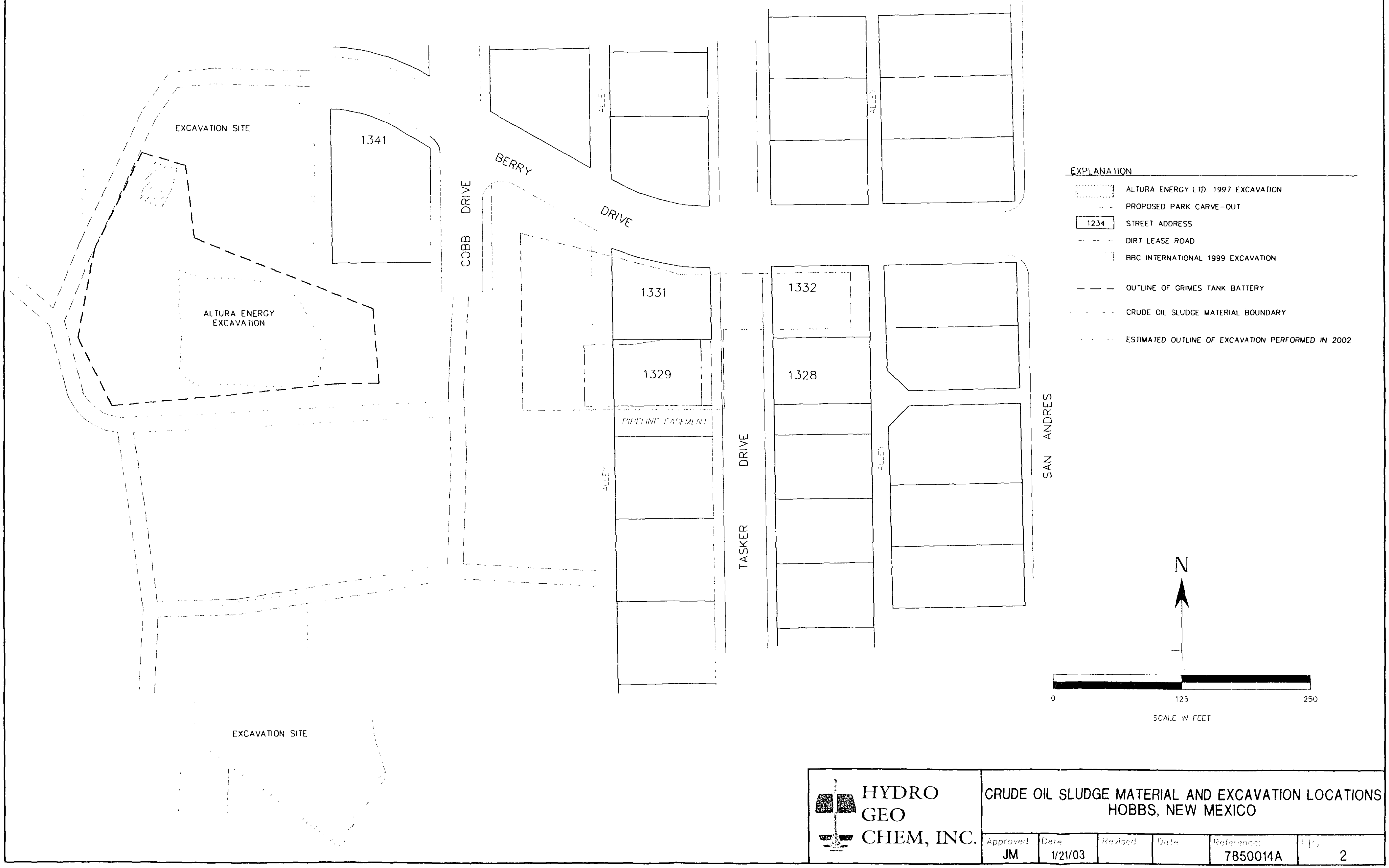
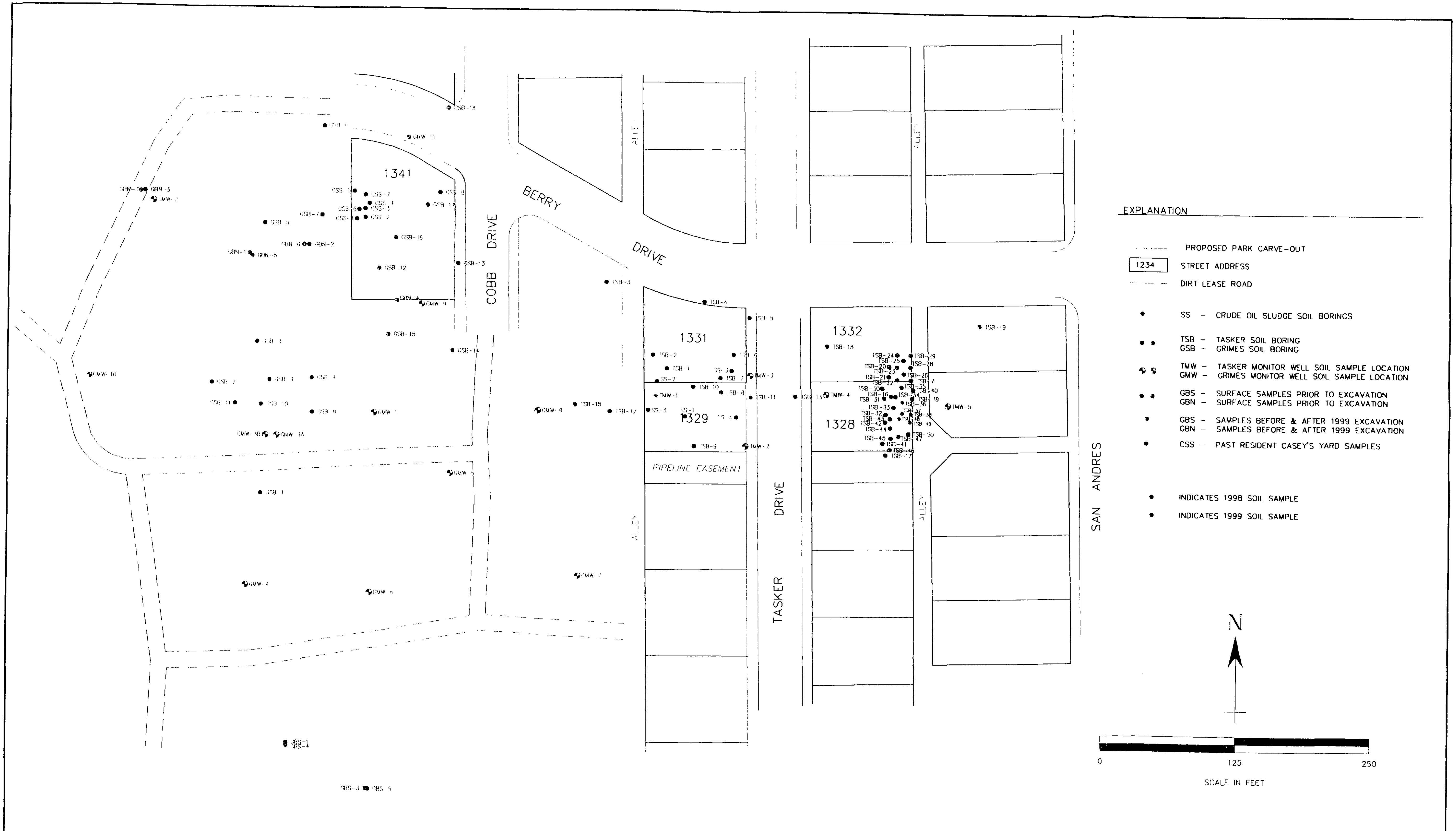


HYDRO
GEO
CHEM, INC.

CRUDE OIL SLUDGE MATERIAL AND EXCAVATION LOCATIONS
HOBBS, NEW MEXICO

Approved	Date	Revised	Date	Reference:	FIG
JM	1/21/03			7850014A	2



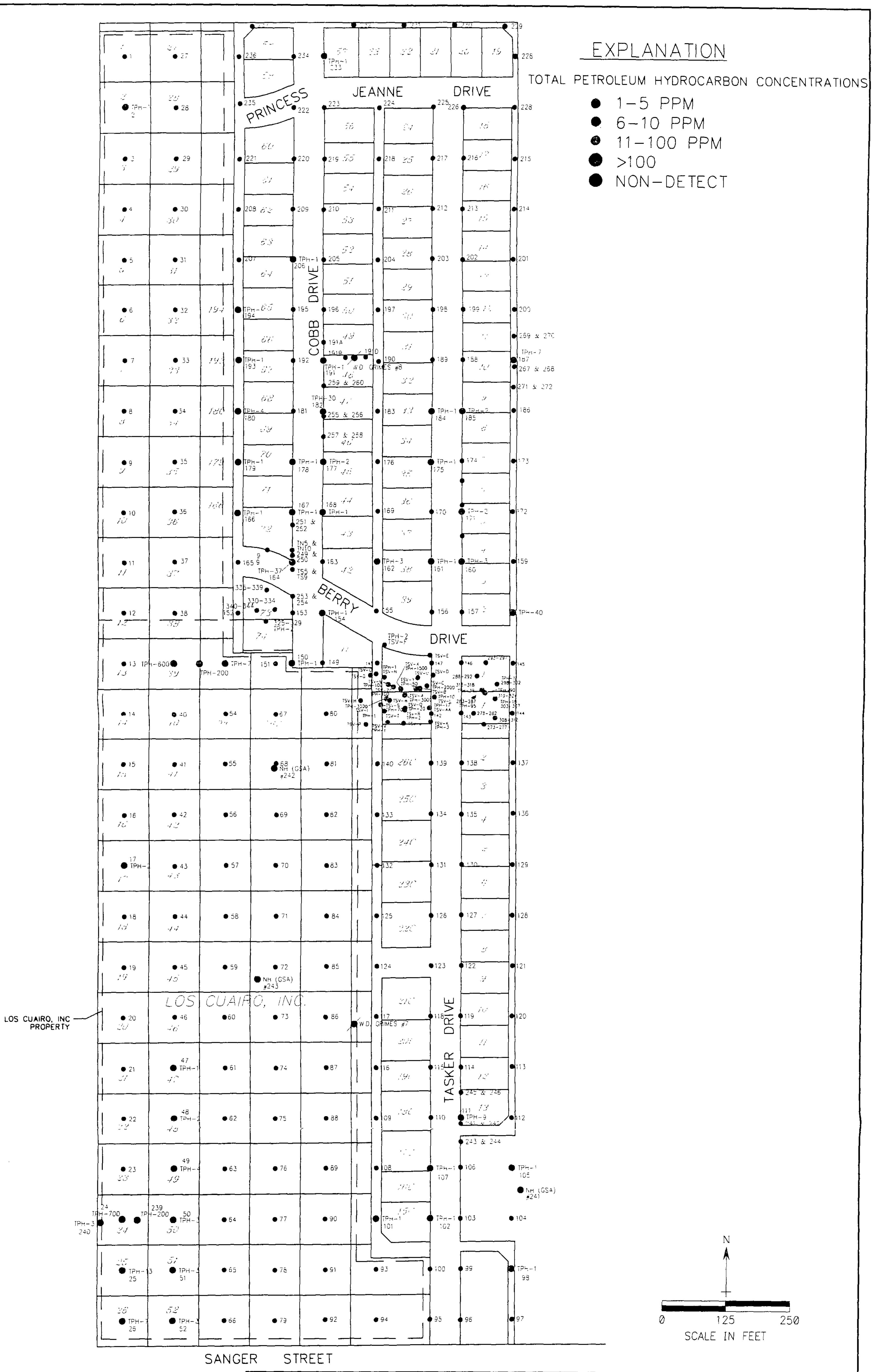
EXPLANATION

- - - -	PROPOSED PARK CARVE-OUT
1234	STREET ADDRESS
— — —	DIRT LEASE ROAD
●	SS – CRUDE OIL SLUDGE SOIL BORINGS
● ●	TSB – TASKER SOIL BORING GSB – GRIMES SOIL BORING
● ●	TMW – TASKER MONITOR WELL SOIL SAMPLE LOCATION GMW – GRIMES MONITOR WELL SOIL SAMPLE LOCATION
● ●	GBS – SURFACE SAMPLES PRIOR TO EXCAVATION GBN – SURFACE SAMPLES PRIOR TO EXCAVATION
●	GBS – SAMPLES BEFORE & AFTER 1999 EXCAVATION GBN – SAMPLES BEFORE & AFTER 1999 EXCAVATION
●	CSS – PAST RESIDENT CASEY'S YARD SAMPLES
●	INDICATES 1998 SOIL SAMPLE
●	INDICATES 1999 SOIL SAMPLE

HYDRO
GEO
CHEM, INC.

SOIL SAMPLE LOCATIONS
HOBBS, NEW MEXICO

Approved	Date	Revised	Date	Reference	FIG.
JM	1/21/03			7850001A	3



HYDRO
GEO
CHEM, INC.

SOIL GAS SAMPLE LOCATION MAP

Approved	Date	Revised	Date	Reference:	FIG:
JM	1/23/03			7850002A	4

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HYDRO
GEO
CHEM, INC.

GROUNDWATER MONITORING WELL LOCATIONS
HOBBS, NEW MEXICO

Approved	Date	Revised	Date	Reference:	FIG
JM	1/21/03			7850004A	5

APPENDIX A

RESUME OF MR. MARK W. KUHN

RESUME OF MARK W. KUHN

EDUCATION:

M.S. (Hydrology), University of Arizona, Tucson, Arizona, 1983.

B.A. (Geology), University of South Florida, Tampa, Florida, 1980.

EXPERIENCE:

Hydro Geo Chem, Inc.

Mr. Kuhn joined Hydro Geo Chem, Inc. in 1981. He is currently Executive Vice-President and senior project manager. Mr. Kuhn has managed over 100 site characterizations, environmental assessments, and remediation projects; including Environmental Protection Agency (EPA) Superfund (CERCLA) investigations of volatile halocarbons; RCRA closure; studies of mixed-waste (radionuclide and organics contamination); groundwater plumes and surface sources associated with electronics, chemical, and aerospace manufacturing; contaminant and methane migration associated with industrial and municipal landfills; petroleum product spills in the vicinity of refineries and leaking underground tanks, waste ponds associated with coal-fired power plants and manufacturing facilities; and biological, vapor extraction, and groundwater sparging remediation projects.

PROJECT WORK INCLUDES:

- Project manager for the Sky Harbor International Airport remediation project in Phoenix, Arizona. On-going project includes remedial feasibility studies and full scale system design to treat approximately 750,000 gallons of Jet-A free product.

- Project manager of a groundwater biosparging project for Shell Oil. Project included design, construction, and operation of the remedial system for a petroleum hydrocarbon release that had impacted multiple off-site properties.

- Project manager to assist in the preparation of Spill Prevention Countermeasure and Control (SPCC) Plans for Arizona Public Service (APS). Modeled overload flow of mineral oil release to predict probabilities and volumes to discharge compliance locations.

- Project manager of a chlorinated hydrocarbon site for the Salt River Project (SRP) in Phoenix. Performed SVE and sparging pilot test. Designed and constructed full-scale soil remediation system.

- Project manager of a soil remediation project at a bulk petroleum hydrocarbon facility for Equiva Services. Characterized, designed/operated remedial system and obtained site closure in a 7-month time frame.

- Expert witness for the defense of a military contractor. Case involves evaluation of surface water sources of NDMA contamination in groundwater.

- Expert witness for a plaintiff's case involving evaluation of environmental impacts to a residential development from historical oil production operations.

- Project manager of a pilot testing program to develop water treatment technologies for Gencorp Aerojet in Sacramento, California. Evaluated, tested and optimized direct UV photolysis and oxidation process for NDMA and 1,4-dioxane.

- Construction and engineering design manager of a groundwater remediation system for the Pinal Creek Group. Project included 404 permitting, archeological/endangered wildlife surveys, property access, constructive permitting, 3,000 gallons per minute wellfield, vertical turbine pumping stations, telemetry system, and 9-mile HDPE pipeline.

- Expert witness to Arizona State Attorney General's Office for a petroleum hydrocarbon case involving soil and groundwater contamination.

- Construction and engineering design manager of a groundwater remediation system for Cyprus Miami Mining Corporation. Withdrawal system included multiple wellfields coupled with in-line booster stations and 3-mile HDPE distribution piping.

- Project manager for a groundwater sparging and vapor extraction design project at the Naval Amphibious Base in San Diego. Simulated unsaturated and saturated zone contaminant removal rates and designed full-scale soil and groundwater remediation system using a three-dimensional, multi-phase contaminant transport model.

- Construction manager for Zero Corporation to install a multi-well, soil vapor extraction (SVE)/groundwater sparging system in Burbank, California. Project included equipment design, permitting, and construction of a 700 standard cubic feet per minute (scfm), 8,000 lb granular activated carbon vapor treatment system.

- Project manager for the Thomas Price Fuel Service Center in Tucson, Arizona. Completed the full-scale corrective action plan for both soils and groundwater for a large refueling facility operated by the City of Tucson. Conceptual design for soils included a combined vapor extraction and bioventing methodology. Groundwater conceptual design entailed natural attenuation assisted through hydraulic plume stabilization. Corrective Action Plan was submitted to and approved by the Arizona Department of Environmental Quality (ADEQ).

- Project manager for an SVE design project at the Reese Air Force Base in Lubbock, Texas. Project included installation of vapor extraction and vapor monitoring wells, vapor and soil sampling for contaminants, and physical parameters. Evaluation of porous media parameters. Development of numerical multi-phase contaminant transport model to design full-scale soil remediation system and predict cleanup performance.

- Project manager for a multiple landfill investigation for the City of Tucson to evaluate volatile organic concentrations and methane distribution in the subsurface.
- Project manager for the operation and maintenance of active methane extraction systems for the City of Tucson. Project included design and construction of methane monitoring wells and routine sample collection from methane monitoring systems.

- Project manager for the T. Price interim soil remediation project for the City of Tucson. Designed interim SVE system. Constructed a dual-screened vapor extraction well. Provided construction management of a propane fired thermal/catalytic oxidizer. Provided operation and maintenance of remediation system.

- Project manager for a RCRA closure for the Evergreen Air Center. Investigation included soil gas and soil sampling for volatile organic and heavy metals contamination due to aircraft stripping operations. Submitted closure plan to and received approval from the ADEQ. Responsible for design and implementation of remediation. RCRA closure was successfully completed in December 1995.

- Project manager for large-scale site characterization at the former BASF facility in Anaheim, California. Project entailed soil gas sampling, soil sampling, installation of groundwater monitoring wells, and groundwater sampling and analysis. Evaluated the potential presence of heavy metals, volatile organics, semi-volatile organics, and PCB's.

- Project manager for a soil remediation project in City of Industry, California for United Technologies. Designed remediation system and predicted contaminant removal efficiencies for chlorinated volatile organics. Supervision and construction management of a multiple extraction injection well SVE system with automatic data acquisition and continuous flow and temperature and concentration monitoring. Implementation and supervision of full-scale operation and maintenance.

- Expert witness for landfill case involving potential soils and groundwater contamination.

- Project manager of a petroleum hydrocarbon feasibility study for Texaco Environmental Services. Project encompasses site characterization and implementation of both soil and groundwater pilot investigations using SVE, bioremediation, and in-situ groundwater sparging.

- Project manager of the Solvent Savers Superfund site in Linklaen, New York. Project involved preparation of Remedial Design Work Plan and implementation of large-scale in-situ and ex-situ SVE technologies for chlorinated and aromatic hydrocarbons.

- Project manager of the operation and maintenance of an SVE system for Texaco Environmental Services. Operation entails oversight and monitoring of a mobile 250 scfm extraction system and a 25 kilowatt thermal oxidizer used to treat vapor prior to atmospheric discharge.
- Project manager for vapor extraction/bioremediation project of diesel contamination for Arizona Public Service. Project involved installation of 15 multiple completion vapor monitoring wells, design and installation of two air extraction/injection systems with carbon treatment, and field monitoring of oxygen, carbon dioxide methane, total hydrocarbons, and BTEX.

- Project manager for a Union Pacific Railroad project to design, construct, and implement a pilot study to evaluate the large-scale feasibility of soil venting to enhance in-situ biological remediation.

- Project manager for HGC second tier ARCS contract for EPA Region IX. Projects included soil gas sampling and analysis, groundwater and soil sampling, and remediation feasibility studies at various Superfund sites.

- Project manager of an SVE pilot test for EPA at the Phoenix-Goodyear Superfund site. Project included drilling of extraction and vacuum venting wells; design and construction of a trailer and vacuum/carbon treatment facility; in-house design and construction of a vacuum pressure data acquisition system; evaluation of carbon treatment efficiency and breakthrough; and determination of air permeabilities, capture zones, evaluation of circulation patterns, volatile organic compound (VOC) recovery efficiencies, and the effect of surface seals.

- Project manager for a large-scale, in-situ biological remediation and vapor extraction program for the Hoechst Celanese Corporation. Project included preparation of corrective action plan for submittal to Texas Water Commission, vapor-phase and biological modeling, remediation design and construction, biological sampling, gas-phase tracer tests, microbe counting and bench scale culture experiments, installation of 400-foot injection/extraction wells, and design and construction of data acquisition system.

- Project manager of a study for a composite materials Fortune 500 firm in the San Francisco Bay area. Study involved the characterization of an 18-acre abandoned disposal site containing halogenated and aromatic hydrocarbons. Investigation included lithologic and geophysical logging, and volatile and semi-volatile organic soil and water sampling. Presented results and work plan to the California Regional Water Quality Control Board.

- Project manager for a halocarbon contamination investigation at an electronics manufacturing firm. Investigation involved the design and implementation of a site characterization plan involving installation and sampling of monitoring wells, vadose zone gas sampling, geophysical logging, hydraulic testing, and soil sampling to evaluate the extent and identify sources of halocarbon contamination.

- Project manager for a chemical recycling center Superfund site in Seymour, Ohio. Project included feasibility study of a vadose zone air stripping remediation program. Performed numerical modeling of compressible gas flow in the unsaturated zone, constructed chemical model to predict mass transport rates of VOCs, and ran the EPA ISCLT atmospheric dispersion model to estimate air emission concentration at the site boundary and hence 70-year lifetime cancer risk factors. Optimized vacuum extraction schedule within EPA constraints to minimize carbon trapping costs.

- Project manager of an emergency response to a phenol spill from a railroad accident near a surface municipal water supply in Philadelphia, Pennsylvania. Risk assessment included field data collection, review of toxicology, and two-dimensional numerical modeling of saturated and unsaturated vertical infiltration coupled to a finite difference solute transport model to predict contaminant impacts on local surface water.

- Project hydrogeologist for the Utah Power and Light hydrologic investigation in Kemmerer, Wyoming. Study included the evaluation of present and future impacts from fly ash tailing ponds, flue-gas desulfurization (FGD) ponds, and evaporation ponds on the local groundwater system. Approach entailed the use of environmental isotopes, geochemistry, and hydraulic testing to calibrate a two-dimensional integrated finite difference model developed in-house for predicting future impacts and to aid in the design of additional waste ponds.

- Project hydrogeologist for FMC's trona plant site in Westvaco, Wyoming. Construction of three-dimensional flow and solute transport model. Project included calibration of flow model using automatic parameter estimation inverse techniques developed in-house, and simulation of solute transport from a number of brine ponds to predict impacts on a multiple aquifer system and local surface water.

- Project manager for the Jim Bridger hydrologic evaluation study for Pacific Power and Light Company in Point of Rocks, Wyoming. Project entailed an extensive field testing program, use of chemical species and environmental isotopes to evaluate extent of waste pond leakage, well hydraulic testing, and artificial tracer tests. Surface seismic and resistivity geophysical survey to determine fracture densities and stratigraphy, and a spontaneous potential survey to evaluate leakage in a lined FGD pond. Calibration of a three-dimensional groundwater flow model using our in-house finite element automatic parameter estimation inverse code.

- Developer of a three-dimensional solute transport model of FGD pond leakage to predict impacts to local groundwater resources. Development of an explicit pond model linked to the integrated finite difference solute transport model that allows prediction of pond filling history, head dependent pond leakage, chemical precipitation, viscosity dependent hydraulic conductivity, and chemical evolution of the waste pond to predict future impacts of existing FGD ponds and to assist in the design of additional ponds.

- Supervised the hydraulic field testing program at the Waste Isolation Pilot Plant near Carlsbad, New Mexico. Responsibilities included the design, supervision of implementation and interpretation of anisotropy, slug, pressure pulse, and aquifer tracer tests.

Prior Experience

Graduate research assistant from 1981 to 1983, University of Arizona, Department of Hydrology. Conducted research in the use of radioisotopes for dating old groundwater. Designed field instrumentation, developed groundwater dating theory, and conducted field work. Thesis titled: *Subsurface Neutron Production and Its Impact on Groundwater Dating.*

Research assistant, 1979 to 1980, University of South Florida, Tampa, Florida. Analyzed groundwater samples for radium-226, performed X-ray analyses, and various other laboratory activities.

PROFESSIONAL REGISTRATIONS:

Qualifying Party, Arizona Commercial Contractor's License, Class AE, Cleanup of Contaminated Groundwater and Soil, #114979

Arizona UST Qualified Consultant, Prequalification No. 1183

SHORT COURSES:

OSHA-SARA Hazardous Waste Site Health and Safety Training, June 1987.

Short course - Design and Construction of Injection and Disposal Wells, given by Johnson Well Screen, March 1986.

PUBLICATIONS:

Tang, J., G.R. Walter, and M.W. Kuhn. 1999. Field Pilot Study of Trench Air Sparging for Remediation of Petroleum Hydrocarbon in Groundwater. In-situ and On-site Bioremediation, International Symposium, San Diego, California.

Kuhn, M.W., G.R. Walter, and H.W. Bentley. 1991. The Use of Soil Gas Surveys to Design Soil Vapor Extraction Systems. American Chemical Society, Division of Environmental Chemistry. 4th Chemical Congress of North America. v. 31, no. 2, p. 181.

Hughes, L.J., D.F. Emer, M.W. Kuhn, H.W. Bentley, and R.M. Tinlin. 1986. Applications of electrical geophysics in mapping groundwater contamination: Surface and Borehole. Geophysical Methods and Ground Water Instrumentation Conference and Exposition, Denver, Colorado.

Kuhn, M.W., G.R. Walter, and V.K. Gupta. 1985. Automatic parameter estimation techniques applied to a multi-well aquifer test. EOS, Transactions American Geophysical Union, v. 66, no. 46, p. 890.

Bentley, H.W., G.R. Walter, and M.W. Kuhn. 1985. Role of Numerical Modeling and Hydrogeology in Waste Site Assessment. Proceedings of the Edison Electric Institute Groundwater Workshop, New Orleans, 34 pp.

Kuhn, M.W., W.A. Stensrud, and G.R. Walter. 1985. Comparison of hydraulic properties of fractured dolomite determined by pressure pulse, slug/bailer, and pumping tests. Proceedings of a Symposium on Hydrogeology of Rocks of Low Permeability, International Association of Hydrogeologists, 17th International Congress.

Kuhn, M.W., S.N. Davis, R.R. Zito, and H.W. Bentley. 1984. Measurements of thermal neutrons in the subsurface. Geophysical Research Letters, American Geophysical Union, v. 11, no. 6, pp. 607-610. June 1984.

Carrera, J., G.R. Walter, M.W. Kuhn, H.W. Bentley, and G. Swanick. 1984. Three-dimensional modeling of saline pond leakage calibrated by INVERT-3, a quasi-three-dimensional, transient, parameter-estimation program. Proceedings of the 1984 Conference on Practical Applications of Ground-Water Modeling, NWWA, Worthington, Ohio.

Walter, G.R., J.J. Ward, and M.W. Kuhn. 1982. Slug test analysis at H-4 site, WIPP. Sandia National Laboratory Technical Report No. 3, Document No. 74-2700.

Zito, R.R., S.N. Davis, H.W. Bentley, and M.W. Kuhn. 1982. Water dating and radionuclide production by subsurface neutrons. The Geological Society of America Abstracts, v. 14, no. 7, p. 653.

SEMINARS AND INVITED LECTURES:

South Coast Air Quality Management District: In-house Seminar. Invited Speaker to Present Vapor Extraction Equipment and Methods, Atmospheric Monitoring Techniques, and Activated Carbon Air Emission Treatment Systems. January 1994.

Kuhn, M.W., G.R. Walter, and H.W. Bentley. Invited speaker on The Use of Soil Gas Surveys to Design Soil Vapor Extraction Systems. American Chemical Society, Division of Environmental Chemistry. 4th Chemical Congress of North America. August 1991.

Brodsky School of Real Estate: Certified Arizona State Instructor for Real Estate Environmental Audit Seminar. May 1990.

Southern Arizona Environmental Management Society: Invited speaker to present Vapor Extraction, Theory, Methods, and Case Studies. April 1989.

NWWA Distinguished Speaker Symposium: Theoretical and Practical Consideration of Flow in Fractured Rocks, Lectured by Shlomo Neuman, December 1987. Invited to present state-of-the-science well hydraulics interpretation techniques.

Department of Hydrology and Water Resources Department, Hydrology Graduate Course #435, April 1987. Invited lecturer on well drilling and construction theory, methods, and techniques.

Department of Hydrology and Water Resources, Hydrology Graduate Course #435, May 1987. Invited lecturer on borehole geophysics, theory, implementation, and interpretation.

American Geophysical Union Conference. Hydrogeology Section: presented paper entitled: Simultaneous Observation Well Interpretation Automatic Parameter Estimation Technique. San Francisco, December 1985.

National Academy of Sciences Seminar. Presented paper entitled: Chlorine-36 Groundwater Dating. Flagstaff, Arizona 1983.

APPENDIX B

LIST OF DOCUMENTS RELIED ON OR CONSIDERED

APPENDIX B

List of Documents Relied On or Considered

Item #	Title	HL #	Author	Year	Location
1	Westgate-Philip Services Corp-Tasker Road Site Assessment Report-(including Map)	02/98	Philip Services	1998	HL: Site Assessment Report Westgate SS-1 to SS-5
2	Site Assessment Analysis Reports Westgate SS-1 to SS-5	02/98	Philip Services	1998	HL: Site Assessment Report Westgate SS-1 to SS-5
3	Site Assessment Investigation Appendices 1 to 5	11/98	Philip Services Corp.	1998	HL: Site Assessment Investigation Appendices 1 to 5
4	Site Assessment Investigation Appendices 6 to 8	11/98	Philip Services	1998	HL: Site Assessment Investigation Appendices 6 to 8
5	Westgate Subdivision, Grimes Battery and Tasker Road Stage 1 Abatement Plan Report Updated 1998 - Westgate GSB-1 to GSB-17 Analytical Results	01/98	BBC International, Inc.; Arcadis Geraghty & Miller	1998	HL: Westgate GSB-1 to GSB-17 Analytical Results
6	Site Assessment Investigation with Appendices I - VII	07/99	BBC International, Inc.; Arcadis Geraghty & Miller	1999	HL: Site Assessment Investigation with Appendices I - VII
7	Site Assessment Investigation - Appendix VIII Only	07/99	BBC International, Inc.; Arcadis Geraghty & Miller	1999	HL: Site Assessment Investigation - Appendix VIII Only
8	1999 Quarterly Groundwater Monitoring Report	04/00	BBC International, Inc.	2000	HL: Miscellaneous Reports and Correspondence
9	1999 Quarterly Groundwater Monitoring Report Copy	04/00	BBC International, Inc.	2000	HL: Miscellaneous Reports and Correspondence
10	Stage 2 Abatement Plan (AP-2) Shell Grimes Lease	05/00	BBC International, Inc.	2000	HL: Miscellaneous Reports and Correspondence
11	Health and Safety Plan for the Westgate Subdivision	05/00	BBC International, Inc.	2000	HL: Miscellaneous Reports and Correspondence
12	Health and Safety Plan for the Westgate Subdivision Remediation Project Copy	05/00	BBC International, Inc.	2000	HL: Miscellaneous Reports and Correspondence
13	Characterization of Potential Air Emissions Associated with Remediation Activities Near the Westgate Subdivision-Phase I Air Monitoring Study Design Plan	05/00	Radian International	2000	HL: Miscellaneous Reports and Correspondence
14	Characterization of Potential Air Emissions Associated with Remediation Activities Near the Westgate Subdivision-Phase I Air Monitoring Study Design Plan Copy	05/00	Radian International	2000	HL: Miscellaneous Reports and Correspondence

APPENDIX B

List of Documents Relied On or Considered

Item #	Title	HL #	Author	Year	Location
15	Westgate Addition-American Environmental Network, Inc. - Results	05/00	Radian International	1998	HL: Miscellaneous Reports and Correspondence
16	Notice of Deficiency Stage 2 Abatement Plan (AP-2) Shell Grimes Lease	05/00	BBC International, Inc.	2000	HL: Miscellaneous Reports and Correspondence
17	Notice of Deficiency Grimes Lease Stage 1 Interim Report	12/98	Roger C. Anderson	1998	HL: Miscellaneous 1998
18	Shell Report to OCD	11/98	BBC International, Inc.	1998	HL: Miscellaneous 1998
19	OCD's Schedule to receive Shell Abatement Report	10/98	William C. Olson	1998	HL: Miscellaneous 1998
20	Meeting with OCD's and Shell	09/98	William C. Olson	1998	HL: Miscellaneous 1998
21	Westgate Subdivision, Grimes Battery and Tasker Road Stage 1 Abatement Plan Addendum	09/98	Wayne Hamilton	1998	HL: Miscellaneous 1998
22	OCD's Requirements and Request for Information	07/98	William C. Olson	1998	HL: Miscellaneous 1998
23	OCD's Approval (with conditions) of Shell's Amended Stage 1 Abatement Plan	07/98	Roger C. Anderson	1998	HL: Miscellaneous 1998
24	WESTGATE-Soil Analyses from the State of NM OCD-Chase Casey	06/98	William C. Olson	1998	HL: Miscellaneous 1998
25	OCD's Re: Soil Analyses	06/98	William C. Olson	1998	HL: Miscellaneous 1998
26	Stage 1 Abatement Plan (Philip Services)	05/98	Philip Services	1998	HL: Miscellaneous 1998
27	Shell Grimes Tank Battery/Tasker Street Summary of Events	04/98		1998	HL: Miscellaneous 1998
28	Grimes Battery and Tasker Road Stage 1 Abatement Work Plan	04/98	Philip Services	1998	HL: Miscellaneous 1998
29	OCD Laboratory Analytical Results of Soil Samples - 1/20/98	03/98	William C. Olson	1998	HL: Miscellaneous 1998
30	State of New Mexico Oil Conservation Division File	02/98	Chris Williams, District 1 Supervisor	1998	HL: Miscellaneous 1998
31	Tasker Road Site Assessment Report	02/98	Philip Services	1998	HL: Miscellaneous 1998
32	Grimes Batter Soil and Groundwater Assessment Report	02/98	Philip Services	1998	HL: Miscellaneous 1998
33	Samples by Philip Environmental	01/98	Philip Environmental	1998	HL: Miscellaneous 1998
34	Samples by Cardinal Laboratories	11/97	Cardinal Laboratories	1997	HL: Miscellaneous 1998
35	OCD previous Notice failed to set out the Time	12/00	Stephen C. Ross	2000	HL: Misc. 1999 to 2000
36	OCD response to WGR request to change the pre-hearing conference	12/00	Stephen C. Ross	2000	HL: Misc. 1999 to 2000
37	OCD Response to WGR Letter 10/16/00 in reference to Stage 2 Abatement Plan proposal	12/00	Roger C. Anderson, Environmental Bureau	2000	HL: Misc. 1999 to 2000
38	OCD Pre-hearing conference with Administrative Order of the OCD	11/00	Stephen C. Ross	2000	HL: Misc. 1999 to 2000

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Item #	Title	HL #	Author	Year	Location
39	WGR ltr to OCD re: Shell Abatement Plan AP-2	10/00	William G. Rosch, III	2000	HL: Misc. 1999 to 2000
40	OCD ltr to WGR re: Shell Abatement Plan AP-2	09/00	Roger C. Anderson/Julie Ayers	2000	HL: Misc. 1999 to 2000
41	Stage 2 Abatement Plan Proposal former Shell Grimes Tank Battery and Westgate Subdivision	03/00	Andrew Sher	2000	HL: Misc. 1999 to 2000
42	OCD response to Linda Foster Complaint	03/00	William C. Olson, Linda Foster, Chris Williams	2000	HL: Misc. 1999 to 2000
43	OCD has reviewed Shell "30-Day Extension Request, Notice of Deficiency"	03/00	William C. Olson	2000	HL: Misc. 1999 to 2000
44	OCD has reviewed Shell "Stage 2 Abatement Plan, Westgate Subdivision Grimes Battery and Tasker Road"	03/00	William C. Olson	2000	HL: Misc. 1999 to 2000
45	SEPCo Requests permission from OCD to backfill the existing Grimes Battery excavation	02/00	Wayne A. Hamilton, Patrick B. McMahon	2000	HL: Misc. 1999 to 2000
46	Notice of Deficiency Stage 2 Abatement Plan (AP-2) Shell Grimes Lease	02/00	William C. Olson	2000	HL: Misc. 1999 to 2000
47	OCD correction of address	02/00	Roger C. Anderson	2000	HL: Misc. 1999 to 2000
48	Stage 2 Abatement Plan Proposal former Shell Grimes Tank Battery and Westgate	01/00	Roger C. Anderson	2000	HL: Misc. 1999 to 2000
49	Comments to Shell Oil Co., Stage 2 Abatement Plan Proposal for the Former Grimes TB site and portions of the Westgate Subdivision	12/99	William G. Rosch, III, Patrick B. McMahon, Roger C. Anderson	1999	HL: Misc. 1999 to 2000
50	Request for Public Hearing and Supplemental comments to Shell Oil Co., Stage 2 Abatement Plan Proposal for the former Grimes TB and Portions of the Westgate Subdivision	12/99	Andrew Sher	1999	HL: Misc. 1999 to 2000
51	Westgate Subdivision, Grimes Battery and Tasker Road State 2 Abatement Plan Public Notice Mailing Affidavit & Mailing List	11/99	Cliff P. Brunson, Patrick B. McMahon, Wayne Hamilton	1999	HL: Misc. 1999 to 2000
52	Notice of Publication (OCD)	11/99	Heidel, Samberson, Newell & Cox	1999	HL: Misc. 1999 to 2000
53	Complaint by Linda Foster	11/99	Heidel, Samberson, Newell & Cox; Patrick B. McMahon; Chris Williams; Linda G. Foster	1999	HL: Misc. 1999 to 2000

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54	Submittal of Stage 2 Abatement Plan	10/99	BBC International, Inc., ARCADIS Geraghty & Miller	1999	HL: Misc. 1999 to 2000
55	Grimes Lease Stage 2 Abatement Plan (AP-2)	10/99	Roger C. Anderson	1999	HL: Misc. 1999 to 2000
56	Tasker Road Stage 1 Abatement Plan Report Recommended Test Sites (Under Shell Ownership)	08/99	William G. Rosch, III, Patrick B. McMahon	1999	HL: Misc. 1999 to 2000
57	OCD Laboratory Analytical Results of Soil Samples that the OCD split with SHELL	08/99	William C. Olson, H. Mitchell Rubenstein, Ph.D.Pinnacle Laboratories, Barringer Laboratories, Inc.	1999	HL: Misc. 1999 to 2000
58	Page Insert for Table 2: Soil Laboratory Results	08/99	Patrick B. McMahon, Cliff Brunson, Wayne Hamilton	1999	HL: Misc. 1999 to 2000
59	Grimes Lease Stage 1 Investigation Report Abatement Plan AP-2	08/99	Roger C. Anderson	1999	HL: Misc. 1999 to 2000
60	Status of the recent Activities related to Abatement Plan for the Shell Grimes Lease	06/99	William C. Olson, Patrick B. McMahon, Cliff Brunson, Wayne Hamilton	1999	HL: Misc. 1999 to 2000
61	Grimes Lease Stage 1 Investigation Report Abatement Plan AP-2	08/99	Roger C. Anderson	1999	HL: Misc. 1999 to 2000
62	Status of the recent Activities related to Abatement Plan for the Shell Grimes Lease	06/99	William C. Olson	1999	HL: Misc. 1999 to 2000
63	Westgate Subdivision, Grimes Battery and Tasker Road Stage 1 Abatement Plan Report (Site Assessment Investigation)	07/99	Cliff P. Brunson	1999	HL: Misc. 1999 to 2000
64	Westgate Subdivision, Stage 1 Abatement Plan Modification Additional Soil Vapor Survey, Site Access Request	05/99	David J. Owens, Wayne Hamilton	1999	HL: Misc. 1999 to 2000
65	Ltr to WGR from OCD Shell Grimes Lease/Tasker Road Site Hobbs, NM	04/99	William C. Olson	1999	HL: Misc. 1999 to 2000
66	OCD has reviewed Shell "Westgate Subdivision East of Tasker Road, Stage 1"	02/99	Roger C. Anderson	1999	HL: Misc. 1999 to 2000
67	Site Safety & Health Plan	01/99	Cliff P. Brunson	1999	HL: Misc. 1999 to 2000
68	Supplemental Grimes Lease Stage 1 Interim Report	01-99	David J. Owens, Wayne Hamilton, Performance Analytical Inc.	1999	HL: Misc. 1999 to 2000

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69	Notice Letter to all Westgate Residence	01/99	Shell Oil Company	1999	HL: Misc. 1999 to 2000
70	HL: Soil Analysis Results 10/99 - Westgate GBS 1-7; GBN 1-7	10/99	Various Laboratories	1999	HL: Soil Analysis Results 10/99 - Westgate GBS 1-7; GBN 1-7
71	Laboratory Analytical Results July 1999 - Order ID Nos. 9807000518-9810000164	1999	Various Laboratories	1999	HL: Laboratory Analytical Results July 1999
72	Laboratory Analytical Results July 1999 - Order ID Nos. 9807000518 - 9809000108	1999	Various Laboratories	1999	HL: Laboratory Analytical Results July 1999
73	Analytical & Quality Control Reports Westgate TSB 1-49	10/99	BBC International, Inc.; Arcadis Geraghty & Miller, Various Laboratories	1999	HL: Analytical & Quality Control Reports Westgate TSB 1-49
74	New Mexico Air Quality Data, 1991-1993	03/98	Environment Department Air Quality Bureau	1998	HL: State of New Mexico Air Quality Bureau - Data for 1994-1996; Hydrogen Sulfide Gas Emergency; OCD Maps
75	Westgate Addition - Shell Western-Contingency Plan for a Hydrogen Sulfide Gas Emergency Involving the North Hobbs Water Flood Unit	09/91	Shell Western E&P Inc.	1991	HL: State of New Mexico Air Quality Bureau - Data for 1994-1996; Hydrogen Sulfide Gas Emergency; OCD Maps
76	OCD Maps - Hobbs Area (4)	09/91	Shell Western E&P Inc.	1991	HL: State of New Mexico Air Quality Bureau - Data for 1994-1996; Hydrogen Sulfide Gas Emergency; OCD Maps
77	Drilling Prognosis North Hobbs (Grayburg-San Andres) Line Wells	ACOSTA 000538	Shell Oil Company		PDF File
78	Proposed Blinebry-drinkard Unit	ACOSTA 000366	Mid-Continent Division Production		PDF File
79	A Program of Water Injection to Improve Crude Oil Recovery	ACOSTA 001231	Unknown		PDF File
80	Free Water Knockout Specifications	ACOSTA 001386	Mid-Continent Division Production	1980	PDF File
81	Report on the Hobbs Field, Lea County, New Mexico	ACOSTA 002320	Mid-Continent Division Production	1938	PDF File
82	Preliminary Waterflood Investigation Grayburg Zone-North Portion of Hobbs Pool	ACOSTA 002352	Moran Oil Producing & Drilling Corp.	1965	PDF File
83	Pressure Maintenance Project, Working Interest Owners Meeting	ACOSTA 002897	Mid-Continent Division Production	1980	PDF File
84	A Program of Water Injection to Improve Crude Oil Recovery	ACOSTA 002876	Unknown		PDF File
85	Agreement for the Exchange of Real Property	ACOSTA 003430	Unknown	1973	PDF File

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86	Quarterly Annulus Survey Results	ACOSTA 005475	Shell Oil Company	1979	PDF File
87	Evaluation of CO2 Enhanced Oil Recovery Potential	ACOSTA 006241	Shell Western E&P Inc.	1984	PDF File
88	Preliminary Report on Salt Water Disposal for the Hobbs Pool	ACOSTA 006806	Rice Engineering & Operating, Inc.	1957	PDF File
89	Gas Transmission and Gathering System Annual Report for Calendar Year 1981	ACOSTA 006904	Shell Oil Company	1981	PDF File
90	Presentation of Results of Casing Failure Study (G/SA) Unit	ACOSTA 006919	Shell Oil Company	1982	PDF File
91	A Program of Water Injection to Improve Crude Oil Recovery	ACOSTA 010081	Unknown		PDF File
92	Drilling Prognosis North Hobbs (Grayburg-San Andres) Infill Wells	ACOSTA 009976	Mid-Continent Division Production	1983	PDF File
93	Proposed North Hobbs Unit CO2 Project	ACOSTA 011498	Shell Oil Company	1983	PDF File
94	Water Injection Well Master Valve Corrosion Problem - North Hobbs (G/SA)	ACOSTA 011600	Shell Development Company	1985	PDF File
95	H2S Contingency Plan, 1984-1985 North Hobbs (G/SA) Infill Drilling Program	ACOSTA 013116	Shell Western E&P Inc.	1984	PDF File
96	Temporary Flare System	ACOSTA 013168	Shell Western E&P Inc.	1989	PDF File
97	Natural Gas Liquids Metering Skid	ACOSTA 013418	Shell Western E&P Inc.		PDF File
98	Quarterly Progress Report, North Hobbs (G/SA) Unit	ACOSTA 014679	Shell Western E&P Inc.	1987	PDF File
99	Memo: Grimes #11, Hobbs Field, Glorieta Potential	ACOSTA 021359	Interoffice Memo: Well File	1979	PDF File
100	North Hobbs HAZOP Update	ACOSTA 015311	C.L. Mann & E.T. Meyer Sr., NMPU	1993	PDF File
101	Worksheet Notes: Production manifold inlet flow line into vessel V101, Production Separator	ACOSTA 015320	Shell Western E&P Inc.	1991	PDF File
102	HAZOPS Summary	ACOSTA 015338	Mike Berman		PDF File
103	Inspection of Well with Protected Casing - Tubing Annulus-Hobbs Field	ACOSTA 016111		1989	PDF File
104	Request of Exception-Annual Witnessed Casing Leak Survey North Hobbs Grayburg/San Andres Unit	ACOSTA 016182	Shell Western E&P Inc.	1987	PDF File
105	Management of Used/Waste Oils Containing PCB's	ACOSTA 017374	Shell Western E&P Inc.	1991	PDF File
106	Waste Shipment Summaries	ACOSTA 017512	Shell Western E&P Inc.	1988	PDF File
107	Memo: Review of Hobbs HAZOP	ACOSTA 017787	Mike Berman	1992	PDF File

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108	Safety and Environmental Impact Survey, North Hobbs Unit Waterflood	ACOSTA 019218	Mid-Continent Division Production	1980	PDF File
109	General Data Pertinent to the Accidental Release of a Potentially Hazardous Quantity of Gas Containing Hydrogen Sulfide	ACOSTA 019452			PDF File
110	Memo: Westgate Field Report for 1/26/1998 - Re Perry House	ACOSTA 019539	Wayne Price	1998	PDF File
111	Memo: Sampling Event at Casey Residence	ACOSTA 019535	Wayne Price	1998	PDF File
112	Form Letter re Numerous Health Issues	ACOSTA 019576	State of New Mexico Department of Health	1998	PDF File
113	Westgate Community - Securing Safety Hazards	ACOSTA 019580	Randy Merker, Environmental Halth Specialist	1998	PDF File
114	Hobbs-Tasker Road Site: Draft Health Survey	ACOSTA 019611	Randy Merker, Environmental Halth Specialist	1998	PDF File
115	Tank Cleaning, Sediment Oil Removal, Transportation of Miscellaneous Hydrocarbons and Disposal Permit	ACOSTA 019670	Shell Western E&P Inc.	1993	PDF File
116	Release Agreement	ACOSTA 019696			PDF File
117	Well Analysis III Report	ACOSTA 019724	Bill Powers	1985	PDF File
118	Disposal Agreement	ACOSTA 021939	Shell Western E&P Inc.		PDF File
119	Letter Re Proposed Naturally Occurring Radioactive Material (NORM) Surveys	ACOSTA 021845	Rice Engineering & Operating, Inc.	1995	PDF File
120	Letter: NORM Salt Water Disposal System	ACOSTA 021858	Rice Engineering & Operating, Inc.	1994	PDF File
121	Hobbs Salt Water Disposal System	ACOSTA 021864	Rice Engineering & Operating, Inc.	1994	PDF File
122	Recommendations for the NHU Injection System	ACOSTA 022257	Shell Western E&P Inc.	1988	PDF File
123	North Hobbs (G/SA) Unit Satellite Status Report	ACOSTA 023372	Shell Oil Company	1982	PDF File
124	Risk-Based Assessment of Soils-Tasker Road Site, Hobbs, New Mexico	ACOSTA 028081	Shell Oil Company	1998	PDF File
125	Addendum to 9/17/99 RBCA Tier I Summary Assessment Report for Westgate Subdivision	ACOSTA 028053	Equilon Enterprises LLC, Houston	2000	PDF File
126	Estimation of Emissions During Soil or Waste Excavation: Volatile Chemical and Odors - Model Basis for Application at RMA	ACOSTA 028642	Equilon Enterprises LLC, Houston	1998	PDF File

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127	Proposal (Rev. 6/21/00) Technical Justification for Soil Cleanup Levels	ACOSTA 028814	William G. Rixey, Dept. of Civil & Environmental Engineering	2000	PDF File
128	Westgate Subdivision, Grimes Batter and Tasker Road Stage 1 Abatement Plan Report (Site Assessment Investigations)	ACOSTA 32733	Shell Exploration and Production Company	1999	PDF File
129	Hobbs, New Mexico - Implementing Stage 2 Abatement Plan	ACOSTA 32788		2001	PDF File
130	HSE Standard	ACOSTA 32794	Shell Exploration and Production Company	2001	PDF File
131	Assessment Work Plan, 1329 Tasker Road, Hobbs, New Mexico	ACOSTA 33401	Shell Exploration and Production Company	1997	PDF File
132	Minutes of Meeting and Site Visit Findings	ACOSTA 33413	Wayne Price	1997	PDF File
133	2000 Quarterly Groundwater Monitoring Report	04/01	BBC International, Inc.	2001	Park-Euclid WQARF Site - Well Logs
134	Westgate Subdivision, Grimes Battery and Tasker Road, Stage 1 Abatement Plan, Updated 1998 Laboratory Analytical Results	07/99	BBC International, Inc.	1999	Park-Euclid WQARF Site - Well Logs
135	W.D. Grimes Well No. 8 Investigation Additional Stage 1 Abatement Plan Activities	03/2001	BBC International, Inc.	2001	

APPENDIX C

NMOCD REGULATIONS

UNLINED

SURFACE IMPOUNDMENT

CLOSURE

GUIDELINES

(FEBRUARY 1993)

New Mexico Oil Conservation Division
1220 S. St. Francis Dr.
Santa Fe, New Mexico 87505

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PREFACE

The following document does not require that currently operating or permitted unlined surface impoundments be closed. This document is to be used only as a guide when closing unlined surface impoundments used for the containment of exploration, production, processing and storage wastes regulated by the New Mexico Oil Conservation Division (OCD).

OCD requires submission and approval of plans and procedures for closure prior to the actual closure of any unlined surface impoundment. Procedures may deviate from the following guidelines if it can be shown that the proposed procedure will remove or isolate contaminants in such a manner that fresh waters, public health and the environment will not be impacted by remaining contaminants. Specific constituents and/or requirements for soil and ground water analysis and/or remediation may vary depending on site specific conditions.

If a number of unlined impoundments are to be closed by a single company, the company may submit one area-wide plan stating the specific location of each unlined impoundment to be closed, along with the procedures to be used during closure. Deviations from approved plans will require OCD notification and approval.

INTRODUCTION

These guidelines are intended to provide guidance for closure of unlined surface impoundments in a manner that assures protection of fresh waters, public health and the environment.

The New Mexico State Engineer has designated fresh waters as all surface waters and ground waters of the state containing 10,000 milligrams per liter or less of total dissolved solids (TDS) for which there is a present or reasonably foreseeable beneficial use. As stated in New Mexico Oil Conservation Commission (OCC) Order No. R-3221-D, "reasonably foreseeable" generally has been taken to mean a time period of not less than 200 years into the future. An unlined surface impoundment is defined as any unlined below grade feature which receives anything other than fresh water. The term "unlined surface impoundment" includes but is not limited to the following types of unlined features: produced water pits, dehydrator pits, blowdown pits, tank drain pits, pipeline drip collector pits, compressor scrubber pits, flare pits, and all other unlined pits which receive exploration, production and processing wastes regulated by the OCD. Excluded from this definition are pits constructed exclusively for drill cuttings and drilling fluids which are regulated under OCD Rule 105.

Prior to commencing closure of an unlined surface impoundment, a closure plan must be submitted to and approved by OCD. A closure plan may apply to more than one unlined impoundment. At a minimum, a closure plan should include the following elements:

1. The locations of all pits to be closed by township, range, section, unit letter and footages or other OCD approved methods.

2. The procedures which will be used to conduct the soil and ground water assessments and the circumstances under which an assessment of ground water will be conducted.

3. The procedures which will be used to manage, remediate, or dispose of contaminated soil and ground water.

I. SITE ASSESSMENT

Prior to final closure (Section VI), the party responsible for an unlined surface impoundment should perform an assessment to determine the extent to which soils and/or ground water may have been impacted by the operation of the impoundment. Assessment results will form the basis of any required remediation. The sites will be assessed for the severity of contamination and potential environmental and public health threats using a risk based ranking system.

The following characteristics must be determined in order to evaluate a sites potential risks, the need for remedial action and, if necessary, the level of cleanup required at the site:

A. GENERAL SITE CHARACTERISTICS

1. Depth To Ground Water

The operator should determine the depth to ground water at each site. The depth to ground water is defined as the vertical distance from the lowermost contaminants to the seasonal high water elevation of the ground water. If the exact depth to ground water is unknown, the ground water depth can be estimated using either local water well information, published regional ground water information, data on file with the New Mexico State Engineer Office or the vertical distance from adjacent ground water or surface water.

2. Wellhead Protection Area

The operator should determine the horizontal distance from all water sources and private, domestic water sources. A water source shall mean wells, springs or other sources of fresh water extraction. Private, domestic water sources shall mean those water sources used by less than five households for domestic or stock purposes.

3. Distance To Nearest Surface Water Body

The operator should determine the horizontal distance to all downgradient surface water bodies. Surface water bodies are defined as perennial rivers, streams, creeks, irrigation canals and ditches, lakes and ponds.

B. SOIL/WASTE CHARACTERISTICS

Soils/wastes within and beneath the unlined surface impoundment should be evaluated to determine the type and extent of contamination at the site. In order to assess the level of contamination at the unlined impoundment, observations should be made of the soils at the surface and a sample of the potentially impacted soils should be taken from the interval at least 3 feet into the undisturbed native soils beneath the bottom of the pit. Samples should be obtained according to the sampling procedures in Sections III.A. and III.B. This may be accomplished using a backhoe, drill rig, hand auger, shovel or other means.

Initial assessment of soil contaminant levels is not required if an operator proposes to determine the final soil contaminant concentrations after a soil removal or remediation pursuant to section IV.A.

Varying degrees of contamination described below may co-exist at an individual site. The following sections describe the degrees of contamination that should be documented during the assessment of the level of soil contamination:

1. Highly Contaminated/Saturated Soils

Highly contaminated/saturated soils are defined as those soils which contain a free liquid hydrocarbon phase or exhibits gross hydrocarbon staining.

2. Unsaturated Contaminated Soils

Unsaturated contaminated soils are those soils which are not highly contaminated or saturated, as described above, but contain measurable concentrations of benzene, toluene, ethylbenzene and xylenes (BTEX) and total petroleum hydrocarbons (TPH). Sampling and analytical methods for determining contaminant concentrations are described in detail in Section III.A. and III.B.

(NOTE: The above definitions apply only to oilfield contaminated soils which are exempt from federal RCRA Subtitle C hazardous waste provisions. Unlined impoundments receiving non-exempt wastes are subject to evaluation for RCRA hazardous waste characteristics.)

C. GROUND WATER QUALITY

If ground water is encountered during the soil/waste characterization of the impacted soils, a sample should be obtained to assess potential impacts on ground water quality. Ground water samples should be obtained using the sampling procedures in Section III.C. If there is a reasonable probability of ground water contamination based upon the level of contaminants in the soils directly beneath the pit or the extent of soil contamination defined during remedial activities, monitor wells may be required to assess potential impacts on ground water and the extent of ground water contamination.

II. SOIL AND WATER REMEDIATION LEVELS

A. SOILS

1. Highly Contaminated/Saturated Soils

Highly contaminated/saturated soils should be remediated insitu or excavated to the maximum extent practicable and remediated using techniques described in Section IV.A.

2. Unsaturated Contaminated Soils

The general site characteristics obtained during the site assessment (Section I.A.) will be used to determine the appropriate soil remediation levels using a risk based approach. Soils which are contaminated by petroleum constituents will be scored according to the ranking criteria below to determine their relative threat to public health, fresh waters and the environment.

a. Ranking Criteria

Depth To Ground Water	Ranking Score
<50 feet	20
50 - 99	10
>100	0

** The contaminant concentration for TPH is the concentration above background levels.

B. GROUND WATER

Contaminated ground water is fresh ground water which contains free phase products, measurable concentrations of dissolved phase volatile organic constituents or other dissolved constituents in excess of the natural background water quality. Ground water contaminated in excess of the New Mexico Water Quality Control Commission (WQCC) ground water standards or natural background water quality will require remediation.

III. SOIL AND WATER SAMPLING PROCEDURES

Below are the sampling procedures for soil and ground water contaminant investigations of unlined surface impoundments that have received RCRA Subtitle C exempt oil field exploration and production wastes. Unlined surface impoundments that have received non-exempt RCRA wastes will be required to be tested to demonstrate that the wastes are not characteristically hazardous according to RCRA regulations.

A. HIGHLY CONTAMINATED OR SATURATED SOILS

The following method is used to determine if soils are highly contaminated or saturated:

1. Physical Observations

Study a representative sample of the soil for observable free petroleum hydrocarbons or immiscible phases and gross staining. The immiscible phase may range from a free hydrocarbon to a sheen on any associated aqueous phase. A soil exhibiting any of these characteristics is considered highly contaminated or saturated.

B. UNSATURATED CONTAMINATED SOILS

The following methods may be used for determining the magnitude of contamination in unsaturated soils:

1. Soil Sampling Procedures for Headspace Analysis

A headspace analysis may be used to determine the total volatile organic vapor concentrations in soils (ie. in lieu of a laboratory analysis for benzene and BTEX but not in lieu of a TPH analysis). Headspace analysis procedures should be conducted according to OCD approved industry standards or other OCD-approved procedures.

Wellhead Protection Area

<1000 feet from a water source,or;
<200 feet from private domestic water source

Yes	20
No	0

Distance To Surface Water Body

<200 horizontal feet	20
200 - 1000 horizontal feet	10
>1000 horizontal feet	0

b. Recommended Remediation Level

The total ranking score determines the level of remediation that may be required at any given site. The total ranking score is the sum of all four individual ranking criteria listed in Section II.A.2.a. The table below lists the remediation level that may be required for the appropriate total ranking score.

(NOTE: The OCD retains the right to require remediation to more stringent levels than those proposed below if warranted by site specific conditions (ie. native soil type, location relative to population centers and future use of the site or other appropriate site specific conditions.)

	Total Ranking Score		
	>19	10 - 19	0 - 9
Benzene(ppm)*	10	10	10
BTEX(ppm)*	50	50	50
TPH(ppm)**	100	1000	5000

* A field soil vapor headspace measurement (Section III.B.1) of 100 ppm may be substituted for a laboratory analysis of the Benzene and BTEX concentration limits.

Accepted OCD procedures are as follows:

a) Fill a 0.5 liter or larger jar half full of sample and seal the top tightly with aluminum foil or fill a one quart zip-lock bag one-half full of sample and seal the top of the bag leaving the remainder of the bag filled with air.

b) Ensure that the sample temperature is between 15 to 25 degrees Celsius (59-77 degrees Fahrenheit).

c) Allow aromatic hydrocarbon vapors to develop within the headspace of the sample jar or bag for 5 to 10 minutes. During this period, the sample jar should be shaken vigorously for 1 minute or the contents of the bag should be gently massaged to break up soil clods.

d) If using a jar, pierce the aluminum foil seal with the probe of either a PID or FID organic vapor meter (OVM), and then record the highest (peak) measurement. If using a bag, carefully open one end of the bag and insert the probe of the OVM into the bag and re-seal the bag around the probe as much as possible to prevent vapors from escaping. Record the peak measurement. The OVM must be calibrated to assume a benzene response factor.

2. Soil Sampling Procedures For Laboratory Analysis

a. <u>Sampling Procedures</u>

Soil sampling for laboratory analysis should be conducted according to OCD approved industry standards or other OCD-approved procedures. Information on specific industry standards may be obtained from the OCD. Accepted OCD soil sampling procedures and laboratory analytical methods are as follows:

i) Collect samples in clean, air-tight glass jars supplied by the laboratory which will conduct the analysis or from a reliable laboratory equipment supplier.

ii) Label the samples with a unique code for each sample.

iii) Cool and store samples with cold packs or on ice.

iv) Promptly ship sample to the lab for analysis following chain of custody procedures.

v) All samples must be analyzed within the holding times for the laboratory analytical method specified by EPA.

b. <u>Analytical Methods</u>

All soil samples must be analyzed using EPA methods, or by other OCD approved methods and must be analyzed within the holding time specified by the method. Below are laboratory analytical methods commonly accepted by OCD for analysis of soil samples analyzed for petroleum related constituents. Additional analyses may be required if the impoundment has been used for anything other than petroleum based fluids or produced water.

i) Benzene, toluene, ethylbenzene and xylene

- EPA Method 602/8020

ii) Total Petroleum Hydrocarbons

- EPA Method 418.1, or;
- EPA Method Modified 8015

C. GROUND WATER SAMPLING

If an investigation of ground water quality is deemed necessary, it should be conducted according to OCD approved industry standards or other OCD-approved procedures. Information concerning specific industry standards may be obtained from the OCD. The following methods are standard accepted OCD methods which can be used to sample and analyze ground water at RCRA exempt sites (Note: The installation of monitor wells is not required if the OCD approves of an alternate ground water investigation or sampling technique):

1. Monitor Well Installation/Location

One monitor well should be installed adjacent to and hydrologically down-gradient from the unlined surface impoundment to determine if protectable fresh water has been impacted by the disposal activities. Additional monitor wells, located up-gradient and down-gradient of the impoundment, may be required to delineate the full extent of ground water contamination if ground water near the pit has been found to be contaminated.

2. Monitor Well Construction

a) Monitor well construction materials should be:

   i) selected according to industry standards;

   ii) chemically resistant to the contaminants to be monitored; and

   iii) able to be installed without the use of glues or adhesives.

b) Monitor wells should be constructed according to OCD approved industry standards to prevent migration of contaminants along the well casing, and with a minimum of five feet of well screen above the water table to accommodate seasonal fluctuations in the static water table.

3. Monitor Well Development

When ground water is collected for analysis from monitoring wells, the wells should be developed prior to sampling. The objective of monitor well development is to repair damage done to the formation by the drilling operation so that the natural hydraulic properties of the formation are restored and to remove any fluids introduced into the formation that could compromise the integrity of the sample. Monitoring well development is accomplished by purging fluid from the well until the pH and specific conductivity have stabilized and turbidity has been reduced to the greatest extent possible.

4. Sampling Procedures

Ground water should be sampled according to OCD accepted standards or other OCD approved methods. Samples should be collected in clean containers supplied by the laboratory which will conduct the analysis or from a reliable laboratory equipment supplier. Samples for different analyses require specific types of containers. The OCD or the laboratory can provide information on the types of containers required for sample collection. The following procedures are accepted by OCD as standard sampling procedures:

a) Monitor wells should be purged of a minimum of three well volumes of ground water using a clean bailer prior to sampling to ensure that the sample represents the quality of the ground water in the formation and not stagnant water in the well bore.

b) Collect samples in appropriate sample containers containing the appropriate preservative for the analysis required. No bubbles or headspace should remain in the sample container.

c) Label the sample containers with a unique code for each sample.

d) Cool and store samples with cold packs or on ice.

e) Promptly ship sample to the lab for analysis following chain of custody procedures.

f) All samples must be analyzed within the holding times for the laboratory analytical method specified by EPA.

5. Ground Water Laboratory Analysis

Samples should be analyzed for potential ground water contaminants contained in the waste stream, as defined by the New Mexico Water Quality Control Commission (WQCC). All ground water samples must be analyzed using EPA methods, or by other OCD approved methods and must be analyzed within the holding time specified by the method. Below are OCD accepted laboratory analytical methods for analysis of ground water samples analyzed for petroleum related constituents. Additional analyses may be required if the impoundment has been used for anything other than petroleum based fluids or produced water.

a. Analytical Methods

i.) Benzene, Toluene, Ethylbenzene and Xylene

- EPA Method 602/8020

ii.) Major Cations and Anions

- Various EPA or standard methods

iii.) Heavy Metals

- EPA Method 6010, or;
- Various EPA 7000 series methods

iv.) Polynuclear Aromatic Hydrocarbons

\- EPA Method 8100

IV. REMEDIATION

The following discussion summarizes alternatives for remediation of contaminated soil and ground water as defined in Section II.A. and II.B. All procedures used are to be approved by OCD prior to commencement of remediation activities. Separate OCD-approval for remediation is not required if OCD has approved a closure plan which includes the site remediation technique for a particular site. All procedures which deviate from the closure plan, however, must be approved by OCD prior to commencement of remediation activities.

In lieu of remediation, OCD may accept an evaluation of risk which demonstrates that the remaining contaminants will not pose a threat to present or foreseeable beneficial use of fresh waters, public health and the environment.

A. SOIL REMEDIATION

When RCRA exempt or RCRA nonhazardous petroleum contaminated soil requires remediation, it should be remediated and managed according to the criteria described below or by other OCD approved procedures which will remove, treat, or isolate contaminants in order to protect fresh waters, public health and the environment.

1. Contaminated Soils

Highly contaminated/saturated soils and unsaturated contaminated soils exceeding the standards described in Section II.A.2.b. should be either:

a) Excavated from the ground until a representative sample from the walls and bottom of the excavation is below the contaminant specific remediation level listed in Section II.A.2.b or an alternate OCD approved remediation level, or;

b) Excavated to the maximum depth and horizontal extent practicable. Upon reaching this limit a sample should be taken from the walls and bottom of the excavation to determine the remaining levels of soil contaminants, or;

c) Treated in place, as described in Section IV.A.2.b.ii. - Treatment of Soil in Place, until a representative sample is below the contaminant specific remediation level listed in Section II.A.2.b, or an alternate OCD approved remediation level, or;

d) Managed according to an OCD-approved alternate method.

2. **Soil Management Options**

All soil management options must be submitted to and approved by OCD prior to commencement of remediation activities. The following is a list of options for either on-site treatment and off-site treatment and/or disposal of contaminated soils:

a. Disposal

Excavated soils may be disposed of at an off-site OCD-approved facility.

b. Soil Treatment and Remediation Techniques

i. Landfarming

Onetime applications of contaminated soils may be landfarmed on location by spreading the soil in an approximately six inch lift within a bermed area. Only soils which do not contain free liquids can be landfarmed. The soils should be disced regularly to enhance biodegradation of the contaminants. If necessary, upon approval by OCD, moisture and nutrients may be added to the soil to enhance aerobic biodegradation.

In some high risk areas an impermeable liner may be required to prevent leaching of contaminants into the underlying soil.

Landfarming sites that will receive soils from more than one location are considered centralized sites and must be approved separately by OCD prior to operation.

ii. Insitu Soil Treatment

Insitu treatment may be accomplished using vapor venting, bioremediation or other OCD approved treatment systems.

iii. Alternate Methods

The OCD encourages alternate methods of soil remediation including, but not limited to, active soil aeration, composting, bioremediation, solidification, and thermal treatment. Use of alternate methods must be approved by OCD prior to implementation.

B. GROUND WATER REMEDIATION

1. Remediation Requirements

Ground water remediation activities will be reviewed and approved by OCD on a case by case basis prior to commencement of remedial activities. When contaminated ground water exceeds WQCC ground water standards, it should be remediated according to the criteria described below.

a. Free Phase Contamination

Free phase floating product should be removed from ground water through the use of skimming devices, total-fluid type pumps, or other OCD-approved methods.

b. Dissolved Phase Contamination

Ground water contaminated with dissolved phase constituents in excess of WQCC ground water standards can be remediated by either removing and treating the ground water, or treating the ground water in place. If treated waters are to be disposed of onto or below the ground surface, a discharge plan must be submitted and approved by OCD.

c. Alternate Methods

The OCD encourages other methods of ground water remediation including, but not limited to, air sparging and bioremediation. Use of alternate methods must be approved OCD prior to implementation.

V. TERMINATION OF REMEDIAL ACTION

Remedial action may be terminated when the criteria described below have been met:

A. SOIL

Contaminated soils requiring remediation should be remediated so that residual contaminant concentrations meet the recommended soil remediation level for a particular site as specified in Section II.A.2.b. Termination of remedial action will be approved by OCD upon a demonstration of completion of remediation as described above.

If soil action levels cannot practicably be attained, an evaluation of risk may be performed and provided to OCD for approval showing that the remaining contaminants will not pose a threat to present or foreseeable beneficial use of fresh water, public health and the environment.

B. GROUND WATER

A ground water remedial action may be terminated if all recoverable free phase product has been removed, and the concentration of the remaining dissolved phase contaminants in the ground water does not exceed New Mexico WQCC water quality standards or background levels. Termination of remedial action will be approved by OCD upon a demonstration of completion of remediation as described in above.

If the water quality standards cannot practicably be attained, an evaluation of risk may be performed and provided to OCD for approval showing that the remaining contaminants will not pose a threat to present or foreseeable beneficial use of fresh waters, human health and the environment.

VI. FINAL CLOSURE

Upon termination of any required soil remedial actions (Section V.) an unlined surface impoundment may be closed by backfilling, contouring to provide drainage away from the site and revegetating the site.

VII. CLOSURE REPORTS

Closure plans should provide a schedule for reporting the results of all closure activities.

GUIDELINES

FOR

REMEDIATION

OF

LEAKS, SPILLS AND RELEASES

(AUGUST 13, 1993)

New Mexico Oil Conservation Division
1220 S. ST. FRANCIS DR.
Santa Fe, New Mexico 87505

TABLE OF CONTENTS

INTRODUCTION

The following document is to be used as a guide on all federal, state and fee lands when remediating contaminants resulting from leaks, spills and releases of oilfield wastes or products. The New Mexico Oil Conservation Division (OCD) requires that corrective actions be taken for leaks, spills or releases of any material which has a reasonable probability to injure or be detrimental to public health, fresh waters, animal or plant life, or property or unreasonably interfere with the public welfare or use of the property. These guidelines are intended to provide direction for remediation of soils and fresh waters contaminated as a result of leaks, spills or releases of oilfield wastes and products in a manner that assures protection of fresh waters, public health and the environment.

Fresh waters (to be protected) includes the water in lakes, playas, surface waters of all streams regardless of the quality of the water within any given reach, and all underground waters containing 10,000 milligrams per liter (mg/l) or less of total dissolved solids (TDS) except for which, after notice and hearing, it is found that there is no present or reasonably foreseeable beneficial use which would be impaired by contamination of such waters. The water in lakes and playas shall be protected from contamination even though it may contain more than 10,000 mg/l of TDS unless it can be shown that hydrologically connected fresh ground water will not be adversely affected.

Procedures may deviate from the following guidelines if it can be shown that the proposed procedure will either remediate, remove, isolate or control contaminants in such a manner that fresh waters, public health and the environment will not be impacted. Specific constituents and/or requirements for soil and ground water analysis and/or remediation may vary depending on site specific conditions. Deviations from approved plans will require OCD notification and approval.

**** Note: **Notification to OCD of leaks, spills and releases does not relieve an operator of responsibility for compliance with any other federal, state or local law and/or regulation regarding the incident. Other agencies (ie. BLM, Indian Tribes, etc) may also have guidelines or requirements for remediation of leaks spills and releases.**

I. NOTIFICATION OF LEAK, SPILL OR RELEASE

Leaks, spills and releases of any wastes or products from oilfield operations are required to be reported to the OCD pursuant to OCD Rule 116 (Appendix A) or New Mexico Water Quality Control Commission (WQCC) Regulation 1-203 (Appendix B). Appendix C contains the phone numbers and addresses for reporting incidents to the OCD district and Santa Fe offices. Notification will include all information required under the respective rule or regulation. Below is a description of some of the information required:

A. RESPONSIBLE PARTY AND LOCAL CONTACT

The name, address and telephone number of the person/persons in charge of the facility/operation as well as the owner and/or operator of the facility/operation and a local contact.

B. FACILITY

The name and address of the facility or operation where the incident took place and the legal location listed by quarter-quarter, section, township and range, and by distance and direction from the nearest town or prominent landmark so that the exact site location can be readily located on the ground.

C. TIME OF INCIDENT

The date, time and duration of the incident.

D. DISCHARGE EVENT

A description of the source and cause of the incident.

E. TYPE OF DISCHARGE

A description of the nature or type of discharge. If the material leaked, spilled or released is anything other than crude oil, condensate or produced water include its chemical composition and physical characteristics.

F. QUANTITY

The known or estimated volume of the discharge.

G. SITE CHARACTERISTICS

The relevant general conditions prevailing at the site including precipitation, wind conditions, temperature, soil type, distance to nearest residence and population centers and proximity of fresh water wells or watercourse (ie. any river, lake, stream, playa, arroyo, draw, wash, gully or natural or man-made channel through which water flows or has flowed).

H. IMMEDIATE CORRECTIVE ACTIONS

Any initial response actions taken to mitigate immediate threats to fresh waters, public health and the environment.

II. INITIAL RESPONSE ACTIONS

Upon learning of a leak, spill or release of any material which has a reasonable probability to injure or be detrimental to public health, fresh waters, animal or plant life, or property or unreasonably interfere with the public welfare or use of the property, the responsible party (RP) should take the following immediate actions unless the actions could create a safety hazard which would result in a threat to personal or public injury:

A. SOURCE ELIMINATION AND SITE SECURITY

The RP should take the appropriate measures to stop the source of the leak, spill or release and limit access to the site as necessary to reduce the possibility of public exposure.

B. CONTAINMENT

Once the site is secure, the RP should take steps to contain the materials leaked, spilled or released by construction of berms or dikes, the use of absorbent pads or other containment actions to limit the area impacted by the event and prevent potential fresh water contaminants from migrating to watercourses or areas which could pose a threat to public health and safety.

C. SITE STABILIZATION

After containment, the RP should recover any products or wastes which can be physically removed from the surface within the containment area. The disposition of all wastes or products removed from the site must be approved by the OCD.

III. SITE ASSESSMENT

Prior to final closure (Section VIII), soils into which nonrecoverable products or wastes have infiltrated and which have a reasonable probability to injure or be detrimental to public health, fresh waters, animal or plant life, or property or unreasonably interfere with the public welfare or use of the property should be assessed for their potential environmental impacts and remediated according to the procedures contained in the following sections. Assessment results form the basis of any required remediation. Sites will be assessed for severity of contamination and potential environmental and public health threats using a risk based ranking system.

The following characteristics should be determined in order to evaluate a sites potential risks, the need for remedial action and, if necessary, the level of cleanup required at the site:

A. GENERAL SITE CHARACTERISTICS

1. Depth To Ground Water

The operator should determine the depth to ground water at each site. The depth to ground water is defined as the vertical distance from the lowermost contaminants to the seasonal high water elevation of the ground water. If the exact depth to ground water is unknown, the ground water depth can be estimated using either local water well information, published regional ground water information, data on file with the New Mexico State Engineer Office or the vertical distance from adjacent ground water or surface water.

2. Wellhead Protection Area

The operator should determine the horizontal distance from all water sources including private and domestic water sources. Water sources are defined as wells, springs or other sources of fresh water extraction. Private and domestic water sources are those water sources used by less than five households for domestic or stock purposes.

3. Distance To Nearest Surface Water Body

The operator should determine the horizontal distance to all downgradient surface water bodies. Surface water bodies are defined as perennial rivers, streams, creeks, irrigation canals and ditches, lakes, ponds and playas.

B. SOIL/WASTE CHARACTERISTICS

Soils/wastes within and beneath the area of the leak, spill or release should be evaluated to determine the type and extent of contamination at the site. In order to assess the level of contamination, observations should be made of the soils at the surface and samples of the impacted soils should be taken in the leak, spill or release area. Observations should note whether previous leaks, spills or releases have occurred at the site. Additional samples may be required to completely define the lateral and vertical extent of contamination. Soil samples should be obtained according to the sampling procedures in Sections V.A. and V.B. This may be accomplished using a backhoe, drill rig, hand auger, shovel or other means.

Initial assessment of soil contaminant levels is not required if an operator proposes to determine the final soil contaminant concentrations after a soil removal or remediation pursuant to section VI.A.

Varying degrees of contamination described below may co-exist at an individual site. The following sections describe the degrees of contamination that should be documented during the assessment of the level of soil contamination:

1. **Highly Contaminated/Saturated Soils**

   Highly contaminated/saturated soils are defined as those soils which contain a free liquid phase or exhibit gross staining.

2. **Unsaturated Contaminated Soils**

   Unsaturated contaminated soils are defined as soils which are not highly contaminated/saturated, as described above, but contain benzene, toluene, ethylbenzene and xylenes (BTEX) and total petroleum hydrocarbons (TPH) or other potential fresh water contaminants unique to the leak, spill or release. Action levels and sampling and analytical methods for determining contaminant concentrations are described in detail in Sections IV. and V.

**** **(NOTE: Soils contaminated as a result of spills, leaks or releases of non-exempt wastes must be evaluated for all RCRA Subtitle C hazardous waste characteristics. The above definitions apply only to oilfield contaminated soils which are exempt from federal RCRA Subtitle C hazardous waste provisions and nonexempt oilfield contaminated soils which are characteristically nonhazardous according to RCRA Subtitle C regulations. Any nonexempt contaminated soils which are determined to be characteristically hazardous cannot be remediated using this guidance document and will be referred to the New Mexico Environment Department Hazardous Waste Program.)**

C. GROUND WATER QUALITY

If ground water is encountered during the soil/waste characterization of the impacted soils, a sample should be obtained to assess the incidents potential impact on ground water quality. Ground water samples should be obtained using the sampling procedures in Section V.C. Monitor wells may be required to assess potential impacts on ground water and the extent of ground water contamination, if there is a reasonable probability of ground water contamination based upon the extent and magnitude of soil contamination defined during remedial activities.

IV. SOIL AND WATER REMEDIATION ACTION LEVELS

A. SOILS

The sections below describe the OCD's recommended remediation action levels for soils contaminated with petroleum hydrocarbons. Soils contaminated with substances other than petroleum hydrocarbons may be required to be remediated based upon the nature of the contaminant and it's potential to impact fresh waters, public health and the environment.

1. Highly Contaminated/Saturated Soils

All highly contaminated/saturated soils should be remediated insitu or excavated to the maximum extent practicable. These soils should be remediated using techniques described in Section VI.A to the contaminant specific level listed in Section IV.A.2.b.

2. Unsaturated Contaminated Soils

The general site characteristics obtained during the site assessment (Section III.A.) will be used to determine the appropriate soil remediation action levels using a risk based approach. Soils which are contaminated by petroleum constituents will be scored according to the ranking criteria below to determine their relative threat to public health, fresh waters and the environment.

a. Ranking Criteria

Depth To Ground Water	Ranking Score
<50 feet	20
50 - 99	10
>100	0

Wellhead Protection Area

<1000 feet from a water source,or;	
<200 feet from private domestic water source	
Yes	20
No	0

Distance To Surface Water Body

<200 horizontal feet	20
200 - 1000 horizontal feet	10
>1000 horizontal feet	0

b. Recommended Remediation Action Level

The total ranking score determines the degree of remediation that may be required at any given site. The total ranking score is the sum of all four individual ranking criteria listed in Section IV.A.2.a. The table below lists the remediation action level that may be required for the appropriate total ranking score.

(NOTE: The OCD retains the right to require remediation to more stringent levels than those proposed below if warranted by site specific conditions (ie. native soil type, location relative to population centers and future use of the site or other appropriate site specific conditions.)

	Total Ranking Score		
	≥19	10 - 19	0 - 9
Benzene(ppm)*	10	10	10
BTEX(ppm)*	50	50	50
TPH(ppm)**	100	1000	5000

* A field soil vapor headspace measurement (Section V.B.1) of 100 ppm may be substituted for a laboratory analysis of the Benzene and BTEX concentration limits.

** The contaminant concentration for TPH is the concentration above background levels.

B. GROUND WATER

Contaminated ground water is defined as ground water of a present or foreseeable beneficial use which contains free phase products, dissolved phase volatile organic constituents or other dissolved constituents in excess of the natural background water quality. Ground water contaminated in excess of the WQCC ground water standards or natural background water quality will require remediation.

V. SOIL AND WATER SAMPLING PROCEDURES

Below are the sampling procedures for soil and ground water contaminant investigations of leaks, spills or releases of RCRA Subtitle C exempt oil field petroleum hydrocarbon wastes. Leaks, spills or releases of non-exempt RCRA wastes must be tested to demonstrate that the wastes are not characteristically hazardous according to RCRA regulations. Sampling for additional constituents may be required based upon the nature of the contaminant which was leaked, spilled or released.

A. HIGHLY CONTAMINATED OR SATURATED SOILS

The following method is used to determine if soils are highly contaminated or saturated:

1. Physical Observations

Study a representative sample of the soil for observable free petroleum hydrocarbons or immiscible phases and gross staining. The immiscible phase may range from a free hydrocarbon to a sheen on any associated aqueous phase. A soil exhibiting any of these characteristics is considered highly contaminated or saturated.

B. UNSATURATED CONTAMINATED SOILS

The following methods may be used for determining the magnitude of contamination in unsaturated soils:

1. Soil Sampling Procedures for Headspace Analysis

A headspace analysis may be used to determine the total volatile organic vapor concentrations in soils (ie. in lieu of a laboratory analysis for benzene and BTEX but not in lieu of a TPH analysis). Headspace analysis procedures should be conducted according to OCD approved industry standards or other OCD-approved procedures. Accepted OCD procedures are as follows:

a) Fill a 0.5 liter or larger jar half full of sample and seal the top tightly with aluminum foil or fill a one quart zip-lock bag one-half full of sample and seal the top of the bag leaving the remainder of the bag filled with air.

b) Ensure that the sample temperature is between 15 to 25 degrees Celsius (59-77 degrees Fahrenheit).

c) Allow aromatic hydrocarbon vapors to develop within the headspace of the sample jar or bag for 5 to 10 minutes. During this period, the sample jar should be shaken vigorously for 1 minute or the contents of the bag should be gently massaged to break up soil clods.

d) If using a jar, pierce the aluminum foil seal with the probe of either a PID or FID organic vapor meter (OVM), and then record the highest (peak) measurement. If using a bag, carefully open one end of the bag and insert the probe of the OVM into the bag and re-seal the bag around the probe as much as possible to prevent vapors from escaping. Record the peak measurement. The OVM must be calibrated to assume a benzene response factor.

2. Soil Sampling Procedures For Laboratory Analysis

a. Sampling Procedures

Soil sampling for laboratory analysis should be conducted according to OCD approved industry standards or other OCD-approved procedures. Accepted OCD soil sampling procedures and laboratory analytical methods are as follows:

i) Collect samples in clean, air-tight glass jars supplied by the laboratory which will conduct the analysis or from a reliable laboratory equipment supplier.

ii) Label the samples with a unique code for each sample.

iii) Cool and store samples with cold packs or on ice.

iv) Promptly ship sample to the lab for analysis following chain of custody procedures.

v) All samples must be analyzed within the holding times for the laboratory analytical method specified by EPA.

b. Analytical Methods

All soil samples must be analyzed using EPA methods, or by other OCD approved methods and must be analyzed within the holding time specified by the method. Below are laboratory analytical methods commonly accepted by OCD for analysis of soil samples analyzed for petroleum related constituents. Additional analyses may be required if the substance leaked, spilled or released has been anything other than petroleum based fluids or wastes.

i) Benzene, toluene, ethylbenzene and xylene

- EPA Method 602/8020

ii) Total Petroleum Hydrocarbons

- EPA Method 418.1, or;
- EPA Method Modified 8015

C. GROUND WATER SAMPLING

If an investigation of ground water quality is deemed necessary, it should be conducted according to OCD approved industry standards or other OCD-approved procedures. The following methods are standard OCD accepted methods which should be used to sample and analyze ground water at RCRA Subtitle C exempt sites (Note: The installation of monitor wells may not be required if the OCD approves of an alternate ground water investigation or sampling technique):

1. Monitor Well Installation/Location

One monitor well should be installed adjacent to and hydrologically down-gradient from the area of the leak, spill or release to determine if protectable fresh water has been impacted by the disposal activities. Additional monitor wells, located up-gradient and down-gradient of the leak, spill or release, may be required to delineate the full extent of ground water contamination if ground water underlying the leak, spill or release has been found to be contaminated.

2. Monitor Well Construction

a) Monitor well construction materials should be:

i) selected according to industry standards;

ii) chemically resistant to the contaminants to be monitored; and

iii) installed without the use of glues/adhesives.

b) Monitor wells should be constructed according to OCD approved industry standards to prevent migration of contaminants along the well casing. Monitor wells should be constructed with a minimum of fifteen

(15) feet of well screen. At least five (5) feet of the well screen should be above the water table to accommodate seasonal fluctuations in the static water table.

3. Monitor Well Development

When ground water is collected for analysis from monitoring wells, the wells should be developed prior to sampling. The objective of monitor well development is to repair damage done to the formation by the drilling operation so that the natural hydraulic properties of the formation are restored and to remove any fluids introduced into the formation that could compromise the integrity of the sample. Monitoring well development is accomplished by purging fluid from the well until the pH and specific conductivity have stabilized and turbidity has been reduced to the greatest extent possible.

4. Sampling Procedures

Ground water should be sampled according to OCD accepted standards or other OCD approved methods. Samples should be collected in clean containers supplied by the laboratory which will conduct the analysis or from a reliable laboratory equipment supplier. Samples for different analyses require specific types of containers. The laboratory can provide information on the types of containers and preservatives required for sample collection. The following procedures are accepted by OCD as standard sampling procedures:

a) Monitor wells should be purged of a minimum of three well volumes of ground water using a clean bailer prior to sampling to ensure that the sample represents the quality of the ground water in the formation and not stagnant water in the well bore.

b) Collect samples in appropriate sample containers containing the appropriate preservative for the analysis required. No bubbles or headspace should remain in the sample container.

c) Label the sample containers with a unique code for each sample.

d) Cool and store samples with cold packs or on ice.

e) Promptly ship sample to the lab for analysis following chain of custody procedures.

f) All samples must be analyzed within the holding times for the laboratory analytical method specified by EPA.

5. Ground Water Laboratory Analysis

Samples should be analyzed for potential ground water contaminants contained in the waste stream, as defined by the WQCC Regulations. All ground water samples must be analyzed using EPA methods, or by other OCD approved methods and must be analyzed within the holding time specified by the method. Below are OCD accepted laboratory analytical methods for analysis of ground water samples analyzed for petroleum related constituents. Additional analyses may be required if the substance leaked, spilled or release has been anything other than a petroleum based fluid or waste.

a. Analytical Methods

i.) Benzene, Toluene, Ethylbenzene and Xylene

- EPA Method 602/8020

ii.) Major Cations and Anions

- Various EPA or standard methods

iii.) Heavy Metals

- EPA Method 6010, or;
- Various EPA 7000 series methods

iv.) Polynuclear Aromatic Hydrocarbons

- EPA Method 8100

VI. REMEDIATION

The following discussion summarizes recommended techniques for remediation of contaminated soil and ground water as defined in Section IV.A. and IV.B. OCD approval for remediation of an individual leak, spill or release site is not required if the company is operating under an OCD approved spill containment plan. All procedures which deviate from the companies spill containment plan must be approved by OCD.

A. SOIL REMEDIATION

When RCRA Subtitle C exempt or RCRA nonhazardous petroleum contaminated soil requires remediation, it should be remediated and managed according to the criteria described below or by other OCD approved procedures which will remove, treat, or isolate contaminants in order to protect fresh waters, public health and the environment.

In lieu of remediation, OCD may accept an assessment of risk which demonstrates that the remaining contaminants will not pose a threat to present or foreseeable beneficial use of fresh waters, public health and the environment.

1. Contaminated Soils

Highly contaminated/saturated soils and unsaturated contaminated soils exceeding the standards described in Section IV.A. should be either:

a) Excavated from the ground until a representative sample from the walls and bottom of the excavation is below the contaminant specific remediation level listed in Section IV.A.2.b or an alternate approved remediation level, or;

b) Excavated to the maximum depth and horizontal extent practicable. Upon reaching this limit a sample should be taken from the walls and bottom of the excavation to determine the remaining levels of soil contaminants, or;

c) Treated in place, as described in Section VI.A.2.b.ii. - Treatment of Soil in Place, until a representative sample is below the contaminant specific remediation level listed in Section IV.A.2.b, or an alternate approved remediation level, or;

d) Managed according to an approved alternate method.

2. Soil Management Options

All soil management options must be approved by OCD. The following is a list of options for either on-site treatment or off-site treatment and/or disposal of contaminated soils:

a. Disposal

Excavated soils may be disposed of at an off-site OCD approved or permitted facility.

b. Soil Treatment and Remediation Techniques

i. Landfarming

Onetime applications of contaminated soils may be landfarmed on location by spreading the soil in an approximately six inch lift within a bermed area. Only soils which do not contain free liquids can be landfarmed. The soils should be disced regularly to enhance biodegradation of the contaminants. If necessary, upon approval by OCD, moisture and nutrients may be added to the soil to enhance aerobic biodegradation.

In some high risk areas an impermeable liner may be required to prevent leaching of contaminants into the underlying soil.

Landfarming sites that will receive soils from more than one location are considered centralized sites and must be approved separately by the OCD prior to operation.

ii. Insitu Soil Treatment

Insitu treatment may be accomplished using vapor venting, bioremediation or other approved treatment systems.

iii. Alternate Methods

The OCD encourages alternate methods of soil remediation including, but not limited to, active soil aeration, composting, bioremediation, solidification, and thermal treatment.

B. GROUND WATER REMEDIATION

1. Remediation Requirements

Ground water remediation activities will be reviewed and approved by OCD on a case by case basis prior to commencement of remedial activities. When contaminated ground water exceeds WQCC ground water standards, it should be remediated according to the criteria described below.

a. Free Phase Contamination

Free phase floating product should be removed from ground water through the use of skimming devices, total-fluid type pumps, or other OCD-approved methods.

b. Dissolved Phase Contamination

Ground water contaminated with dissolved phase constituents in excess of WQCC ground water standards can be remediated by either removing and treating the ground water, or treating the ground water in place. If treated waters are to be disposed of onto or below the ground surface, a discharge plan must be submitted and approved by OCD.

c. Alternate Methods

The OCD encourages other methods of ground water remediation including, but not limited to, air sparging and bioremediation. Use of alternate methods must be approved by OCD prior to implementation.

VII. TERMINATION OF REMEDIAL ACTION

Remedial action may be terminated when the criteria described below have been met:

A. SOIL

Contaminated soils requiring remediation should be remediated so that residual contaminant concentrations are below the recommended soil remediation action level for a particular site as specified in Section IV.A.2.b.

If soil action levels cannot practicably be attained, an evaluation of risk may be performed and provided to OCD for approval showing that the remaining contaminants will not pose a threat to present or foreseeable beneficial use of fresh water, public health and the environment.

B. GROUND WATER

A ground water remedial action may be terminated if all recoverable free phase product has been removed, and the concentration of the remaining dissolved phase contaminants in the ground water does not exceed New Mexico WQCC water quality standards or background levels. Termination of remedial action will be approved by OCD upon a demonstration of completion of remediation as described in above.

VIII. FINAL CLOSURE

Upon termination of any required remedial actions (Section VII.) the area of a leak, spill or release may be closed by backfilling any excavated areas, contouring to provide drainage away from the site, revegetating the area or other OCD approved methods.

IX. FINAL REPORT

Upon completion of remedial activities a final report summarizing all actions taken to mitigate environmental damage related to the leak, spill or release will be provided to OCD for approval.

APPENDIX D

CHEMICAL REFERENCES

From EPA & others, 1999.

Appendix 6A

Composition of Crude Oil and Refined Products

Appendix 6A

Composition of Crude Oil and Refined Products

Crude oils can vary greatly in composition, viscosity, density, and flammability. They can be found in a continuum ranging from highly flammable, light liquids (similar to gas condensate), to highly viscous and heavy tar-like materials. Organic compounds range from methane to extremely heavy hydrocarbon molecules with up to 80 carbon atoms. The chemical composition of crude varies between regions and even within the same geologic formation.

No two batches of crude oil are chemically identical. Crude oil is categorized based on the molecular weight distribution of their constituents, and distinctions are made between light, medium, and heavy crude oil. The EPC pipeline carried at least 22 types of crude oil during its operation between 1950 and 1995. In Table 6A-1, crude oil parameters were averaged for these 22 types based on Exxon crude oil assay sheets. No data are available on the amount of crude oils shipped, so this is not a weighted average. From the data, it appears the EPC pipeline carried mostly medium and heavy crude oil. A study done by the National Research Council in 1985 titled, *Oil in the Sea, National Academy Press* cited in Jones and Neuse (1995), was used to develop a summary compositional analysis of crude oil. This typical crude oil composition is provided in Table 6A-2.

Crude oil is composed of varying fractions of different boiling point ranges of hydrocarbon mixtures. The major fractions are defined as:

- Light ends;
- Light naphtha;
- Medium naphtha;
- Heavy naphtha;
- Kerosene;
- Light gas oil;
- PGO; and
- Residual oil.

The most flammable components are in the light ends through medium naphtha fractions, which together form a mixture somewhat similar in properties to gasoline. The heavy naphtha through residual fractions reflect properties typically perceived as those associated with oils.

The aromatic components of the crude oil, found primarily within medium to heavy naphtha fractions and gas oil fractions, include benzene, a known human carcinogen. Other aromatic compounds include toluene, ethylbenzene, and xylene. These aromatic compounds have relatively high solubilities in water, compared with other hydrocarbons.

Refined products, to be carried by the Longhorn pipeline, include various gasoline grades, diesel fuel, and jet fuel. As with crude oil, gasoline is also a complex mixture of hydrocarbons. Gasoline contains more lower molecular weight hydrocarbons than crude oil, and higher fractions of both light hydrocarbons and aromatics. The hazard level of these materials must be considered on two levels: 1) their impact should they contaminate surface water or ground water, and 2) their potential to ignite and explode. To adequately model worst-case scenarios, a product most likely to rank high on both scales was selected. To accurately represent the worst-case gasoline composition that could be transported through the Longhorn pipeline, the survey composition was modified to reflect a gasoline composition containing MTBE (methyl tertiary-butyl ether).

From the point of view of toxicity and environmental impact, benzene and MTBE have greater concern. Benzene is the primary known carcinogen in gasoline. It is one of the most water-soluble hydrocarbons at 1,700 milligrams per liter (mg/L). There are also a number of hydrocarbons closely related to benzene, that have relatively high solubilities. As a result of the relatively high solubility of mono- and dialkylbenzenes, benzene-toluene-ethylbenzene-xylene (BTEX) tends to dominate the dissolved hydrocarbons in water. BTEX is readily oxidized microbiologically, provided other microbial nutrients are sufficiently available. This natural attenuation of BTEX typically constrains the extent of plume spread in contaminated water and soils, as biodegradation destroys the BTEX at the edge of the plume.

MTBE is a suspected carcinogen by some. MTBE is very mobile and has a low odor and taste threshold. This makes contaminated drinking water unpalatable at concentrations as low as 20 micrograms per liter. MTBE's mobility is due to three factors: solubility, diffusivity, and lack of biodegradability. Up to 4.8 percent MTBE dissolves in water, it adsorbs very poorly to soil, and very little biodegradation has been observed in natural conditions. As a result, MTBE usually migrates substantially ahead of a hydrocarbon plume.

In summary, MTBE and benzene are the prime water contaminants of concern for fuel hydrocarbon spills. Gasolines are the lightest, most volatile, and flammable of the products that could be carried by the Longhorn pipeline. Gasolines are the only products with the potential to contain MTBE. They also have the highest benzene content. For these reasons, gasoline was identified as the worst-case product to be carried by the pipeline.

The model gasoline composition for this study is provided in Table 6A-3. An existing gasoline composition (without MTBE) survey was reviewed (LUFT, 1988) and it was concluded that the hydrocarbon composition in this survey adequately represents the typical flammability range of gasolines. To accurately represent the worst-case gasoline that could be transported through the Longhorn pipeline, the survey composition was modified to reflect a gasoline composition containing MTBE.

First, the benzene concentration was adjusted. The Longhorn pipeline specifies a maximum benzene content of 4.9 percent by weight in the products carried. To properly represent a worst-case relative to benzene concentration, the LUFT survey average benzene concentration of 1.8 percent (wt) was replaced with the Longhorn pipeline product specification of 4.9 percent.

Gasoline blends may contain up to 15 percent MTBE, so this percentage was added as the worst-case. After making these two changes, the fractions of the other components were adjusted so that the total would still equal 100 percent.

Table 6A-1. Composition of Crude Oil Carried by EPC Pipeline

Exxon PL/Longhorn	Historical Crude Assays												
Crude Type:	**Conroe**	**Gulf Coast Mix**	**Salt Flat**	**Salt Flat Mix 1**	**Salt Flat Mix 2**	**Salt Flat Mix 3**	**W Coast Hvy**	**W. Coast Sour**	**W Texas Intermed. 1**	**W Texas Intermed. 2**	**W Texas Intermed. Crane**	**W Texas Intermed. 3**	**W Texas Intermed. Monah.**
API Gravity	37.4	40.3	37.0	34.2	32.6	35.5	23.2	29.0	38.0	40.5	40.9	40.3	37.2
Sulfur, wt%	0.07	0.08	0.58	0.80	1.27	0.78	1.02	0.80	0.35	0.34	0.34	0.41	0.43
H_2S, ppm						60		2	1				
Light ends, Vol%													
C2 – hydrocarbons	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.06	0.00	0.04	0.05	0.05
C3- hydrocarbons	0.22	0.11	0.17	0.04	0.18	0.09	0.01	0.15	0.72	0.40	0.81	0.40	0.55
IC4 (isobutane)	0.19	0.26	0.18	0.06	0.13	0.09	0.07	0.17	0.41	0.40	0.39	0.23	0.25
NC4 (Normal butane)	0.47	1.51	0.36	0.15	0.56	0.21	0.51	0.96	2.38	1.91	1.88	1.00	1.48
IC5 (Isopentane)	0.43	1.44	0.54	0.24	0.61	0.25	1.13	1.57	1.24	1.27	1.09	0.81	0.90
NC5 (Normal Pentane)	0.48	1.83	0.50	0.25	0.81	0.32	1.29	1.79	1.94	1.95	1.89	1.52	1.61
Sum C2-C5	1.8	5.2	1.8	0.7	2.3	1.0	3.0	4.6	6.8	5.9	6.1	4.0	4.8
Light Naphthene (bp<175F)													
Volume %	4.38	8.52	3.67	2.25	4.64	2.77	5.90	8.24	7.65	9.04	8.92	7.59	7.31
Reid Vapor Pressure (psia)		10.1	8.9	7.9	9.3	8.1	10.6	10.7	10.6	9.8	9.8	9.1	9.7
Medium Naphtha (175<bp<250F)													
Volume %	9.11	10.09	6.77	4.5	5.97	5.44	5.05	6.78	8.21	10.63	11.77	11.57	8.03
Aromatics Vol.%	19.2	12.5	4.8	4.5	8.3	7.5	5.8	8.1	3.8	5.4	10.8	5.6	4.2
Naphthene Vol.%	50.3	45.3	35.9	30.4	33.9	30.5	47.7	39.6	41.5	52.2	43.0	39.9	45.7
Paraffins Vol.%													
Sum	69.5	57.8	40.7	34.9	42.2	38	53.5	47.7	45.3	57.6	53.8	45.5	49.9
Heavy Naphtha (250<bp<375F)													
Volume %	18.2	16.7	16.2	12.9	12.1	15.43	8.67	12.2	13.5	16.2	16.71	17.89	13.23
Aromatic Vol.%	35.7	19.9	11.0	10.9	11.1	11.4	13.4	15.8	8.2	12.0	16.7	11.0	8.7
Naphthenes Vol.%	31.0	38.1	38.2	33.6	33.6	35.2	52.4	39.7	43.3	43.3	39.1	36.6	45.5
Paraffins Vol.%													
Sum	66.7	58.0	49.2	44.5	44.7	46.6	65.8	55.5	51.5	55.3	55.8	47.6	54.2
Kerosene (375<bp<650F)													
Volume %	28.68	19.63	19.84	20.07	16.95	20.19	12.02	15.31	15.62	16.88	17.26	17.38	15.23
Light Gasoil (530<bp<650F)													
Volume %	18.19	13.56	13.43	16.68	12.34	14.88	11.37	11.88	11.18	11.30	11.72	11.90	11.57
PGO (650<bp<1049F)													
Volume %	19.17	23.50	30.80	31.08	30.50	33.50	31.84	26.40	29.90	24.30	23.90	24.20	32.30
Aromatics Vol.%	8.4	8.4	8.5	7.6	10.5	9.5	17.1	16.4	10.2	8.4	11.0	11.4	10.4
Naphthene Vol.%	30.5	28.2	28.2	31.5	31.9	29.8	52.1	49.2	32.5	30.1	31.2	32.2	32.1
Residual Oil (bp>1049F)													
Volume %	1.40	6.10	8.60	12.24	16.60	7.40	24.56	17.89	10.40	9.00	6.60	7.80	10.00
Sum Volume %	100.9	103.3	101.0	100.5	101.4	100.6	102.4	103.4	103.2	103.2	103.0	102.3	102.5

Table 6A-1. (Continued)

	Exxon PL/Longhorn											
Crude Type:	**W Texas Sour Kemper**	**W Texas Sour 2**	**W Texas Sour 1**	**Yates**	**Yates Mix**	**Prudhoe 1**	**Prudhoe 2**	**Prudhoe 3**	**Point Arguello**	**Average**	**Fractions Vol.%, approx. Cn**	
API Gravity	32.6	31.8	32.1	28.9	29.4	27.1	27.5	24.9	19.0	32.7		
Sulfur, wt%	1.92	2.05	1.73	1.59	1.49	1.02	0.97	1.06	4.30	1.1		
H_2S, ppm				118	189				74.0			
Light ends, Vol%												
C2 – hydrocarbons	0.08	0.02	0.00	0.00	0.00	0.05	0.09	0.01	0.10	0.03		
C3 – hydrocarbons	0.52	0.5	0.73	0.06	0.16	0.38	0.66	0.10	0.69	0.35		
IC4 (Isobutane)	0.45	0.25	0.38	0.15	0.22	0.05	0.09	0.01	0.10	0.21		
NC4 (Normal butane)	1.35	0.86	0.94	0.42	0.54	0.30	0.43	0.08	0.45	0.85		
IC5 (Isopentane)	1.12	0.97	0.98	0.91	0.89	0.55	0.63	0.12	0.67	0.83		
NC5 (Normal pentane)	1.16	1.09	0.93	0.20	0.30	0.63	0.67	0.18	0.71	1.00		
Sum C2-C5	4.7	3.7	4.0	1.7	2.1	2.0	2.6	0.5	2.7	3.27	3.21	Light ends
Light Naphtha (bp<175F)												(C2-C5)
Volume %	6.91	6.33	6.74	3.66	3.54	3.87	4.00	1.54	3.91	5.52		
Reid Vapor Presence (psia)	9.8	9.6	9.3	9.6	10.1	9.2	9.5	7.6	9.9	9.5		
Medium Naphtha (175<bp<250F)												
Volume %	6.99	7.45	7.01	5.09	5.62	5.51	5.31	3.55	4.51	7.04		
Aromatic Vol.%	11.0	11.6	6.5	3	0.4	14.5	15.9	15.8	6.7	8.5		
Naphthnens Vol.%	40.4	34.3	49.8	42.3	44.5	25	24.2	33.2	29.9	39.07		
Paraffins Vol.%						60.4	59.9	51.0	63.4	58.7		
Sum	51.4	45.9	56.3	45.3	44.9	99.9	100.0	100.0	100.0	58.19		
Heavy Naphtha (250<bp<375F)												
Volume %	12.70	13.39	12.90	12.85	12.52	10.49	9.75	8.52	8.63	13.26	25.35	Naphta
Aromatics Vol.%	18.0	18.2	16.1	10.0	7.8	21.3	21.1	22.5	16.7	15.3		(C6-C10)
Naphthenes Vol.%	43.5	38.2	47.2	52.3	55.9	36.5	35.2	34.5	40.0	40.6		
Paraffins Vol.%						42.2	43.8	43.0	43.3	43.1		
Sum	61.5	56.4	63.3	62.3	63.7	100.0	100.1	100.0	100.0	63.8		
Kerosene (375<bp<650F)												
Volume %	16.00	15.89	15.80	16.85	16.65	16.23	16.17	16.20	11.46	17.11	16.80	Kerosene
Light Gasoil (530<bp<650F)												(C10-C12)
Volume %		11.90	12.09	12.21	13.14	12.75	12.00	14.19	8.9	12.69	12.46	LtGO
PGO (650<bp<1049F)												(C12-C20)
Volume %	31.80	29.40	31.10	30.67	33.30	30.28	32.72	37.60	24.21	29.20	28.68	PGO
Aromatics Vol.%	14.7	11.9	13.6	12.8	14.6	15.2	11.7	14.0	16.3	11.9		(C20-C40)
Naphthenes Vol.%	38.4	39.5	41.7	40.9	41.3	42.3	42.0	47.2	36.9			
Residual Oil (bp>1049F)												
Volume %	11.20	14.00	12.40	18.04	14.30	20.05	18.76	18.18	37.04	13.75	13.50	Resid
												(>C40)
Sum Volume %	102.3	102.1	102.0	101.1	101.2	101.1	101.3	100.3	101.4	101.8	100.00	

Table 6A-2. Representative Characteristics of Crude Oil Carried by the EPC Pipeline

Based on Historical Crude Assays					
				Fractions	
	High	Low	Average	Vol.%	Name & Approx.
General					
API Gravity	40.9	19.0	32.7		C-range
Sulfur, wt%	4.3	0.1	1.1		
H2S, ppm [1]	189.0	1.0	74.0		
Light ends, Vol%					
C2 – hydrocarbons	0.10	0.00	0.03		
C3 – hydrocarbons	0.81	0.01	0.35		
iC4 (Isobutane)	0.45	0.01	0.21		
nC4 (Normal butane)	2.38	0.08	0.85		
iC5 (Isopentane)	1.57	0.12	0.83		
nC5 (Normal pentane)	1.95	0.18	1.00		
Sum C2-C5	6.75	0.50	3.27	3.21	Light ends
Light Naphtha (bp<175F)					(C2-C5)
Volume %	9.0	1.5	5.5		
Reid Vapor Pressure (psia)	10.7	7.6	9.5		
Medium Naphtha (175<bp<250F)					
Volume %	11.8	3.6	7.0		
Aromatics Vol.%	19.2	0.4	8.5		
Naphthenes Vol.%	52.2	24.2	39.1		
Paraffins Vol.% [1]	63.4	51.0	58.7		
Heavy Naphtha (250<bp<375F)					
Volume %	18.2	8.5	13.3	25.35	Naphta
Aromatics Vol.%	35.7	7.8	15.3		(C6-C10)
Naphthenes Vol.%	55.9	31.0	40.6		
Paraffins Vol.% [1]	43.8	42.2	43.1		
Kerosene (375<bp<650F)					
Volume %	28.7	11.5	17.1	16.80	Kerosene
Light Gasoil (530<bp<650F)					(C10-C12)
Volume %	18.2	8.9	12.7	12.46	LtGO
PGO (650<bp<1049F)					(C12-C20)
Volume %	37.6	19.2	29.2	28.68	PGO
Aromatics Vol.%	17.1	7.6	11.9		(C20-C40)
Naphthenes Vol.%	52.1	28.2	36.9		
Residual Oil (bp>1049F)					
Volume %	37.0	1.4	13.8	13.50	Resid
					(>C40)

[1] Not available for most crudes carried.

Table 6A-3. Model Gasoline Composition [1]

			Properties		
Carbon Number	Compound	Mass %	Solubility (mg/L)	Vapor Pressure (atm)	Henry's Law Coefficient
Straight-chain Alkanes					
4	C4 (Butanes)	3.67	61.4	2.4	38.7
5	C5 (Pentanes)	7.08	38.5	0.675	51.7
6	C6 (Hexanes)	1.59	9.5	0.199	73.9
7	C7 (Heptanes)	0.96	2.93	0.0603	84.3
8	C8 (Octanes)	0.76	0.66	0.0178	126
	Subtotal	**14.07**			
Branched Alkanes					
6	2,3-Dimethyl butanes	0.91	19.1	31.6	58.3
5	Isopentanes	6.90	13.8	0.904	193
6	2-Methyl pentanes	2.87	13.8	0.278	71.1
6	3- Methyl Pentanes	2.04	12.8	0.25	68.7
7	2,4-Dimethyl Pentanes	0.82	4.06	0.129	130
7	2,3-Dimethyl Pentanes	1.91	5.25	0.0906	70.7
8	2,2,4-Trimethyl Pentanes	2.08	2.44	0.0647	124
8	2,3,3-Trimethyl pentanes	0.99			
8	2,3,4-Trimethyl Pentanes	1.24	2	0.0355	83
7	2-Methyl hexanes	0.78	2.54	0.0867	140
7	3-Methyl hexanes	0.88	3.3	0.081	101
9	2,2,5-Trimethyl hexanes	2.58	1.15	0.0218	99.5
9	2,3,5-Trimethyl hexanes	0.48			
8	2-Methyl heptanes	0.65	0.85	0.0257	141
8	3-Methyl heptanes	0.92	0.792	0.0258	152
10	2,2,4-Trimethyl heptanes	0.77			
	Subtotal	**26.83**			
Branched Alkenes					
6	2-Methyl-2-butene	0.95			
	Subtotal	**0.95**			
Alkyl Benzenes					
6	Benzene	4.90	1,780	0.125	0.225
7	Toluene	10.43	515	0.0375	0.274
8	otho-xylene	1.37	220	0.0115	0.228
8	meta-xylene	1.50	160	0.0109	0.295
8	para-xylene	2.40	215	0.0115	0.233
8	Ethylbenzene	0.99	152	0.0125	0.358
9	1-Methyl-4-Ethylbenzene	0.50	95	0.0039	0.202
9	1-Methyl-3-Ethylbenzene	1.35		0.00386	
9	1,2,4-Trimethylbenzene	1.68	57	0.00266	0.23
	Subtotal	**26.18**			

Table 6A-3. (Continued)

Carbon Number	Compound	Mass %	Properties		
			Solubility (mg/L)	Vapor Pressure (atm)	Henry's Law Coefficient
	Benzo(a)pyrene	1.27E-04	3.80E-03	2.10E-10	1.86E-05
	Subtotal	1.27E-04			
	MTBE	15.00	48,000	0.309	
	Other	16.97			
	Total	100.00			

[1] 15 percent MTBE, 4.9 percent Benzene, according to Longhorn product specs (RAD 05138-05155)

Source: LUFT 1988

U.S. EPA and American Petroleum Institute Will Study Mercury in Crude Oil

The United States Environmental Protection Agency (U.S. EPA), in cooperation with the American Petroleum Institute (API), has initiated a project to determine the mercury content of crude oil processed in the United States. Mercury Technology Services (S. Mark Wilhelm, Program Manager) is managing the project for U.S. EPA and API. Contributing laboratories include Frontier Geosciences (Seattle, WA), CEBAM Analytical (Seattle, WA) and Texas A&M University.

The focus of the project is to determine the mean concentration and range of concentrations of total mercury in crude oil in a statistical fashion. Data generated in the course of the project will be used to estimate an upper limit to the contribution of mercury in crude oil to anthropogenic mercury emissions in the United States. Portions of the project will examine analytical issues, determine concentration variance in crude oil streams and build a database on total mercury concentrations in processed crude oil.

Background

The concentration of mercury in crude oil is important to the task of tracking the path of mercury in geologic materials to atmospheric, marine and terrestrial pools. Considerable effort has been devoted to measuring mercury in coal and to understanding the mechanisms by which mercury in coal enters the biosphere. An obvious analogy exists between mercury in coal and mercury in petroleum. Although post-combustion pathways for mercury in coal and petroleum are similar, the absolute amounts and species generated by crude oil processing and liquid fuel combustion remain uncertain. Central to these questions are the concentration and species distribution of mercury in crude oil.

Currently available data suggest that the concentrations of mercury in crude oils lie in the range of parts per trillion (g/g) to parts per million. Some crude oils have concentrations below the detection limits of the best analytical methods currently available (approximately 100 ppt). The highest reported concentration for mercury in crude oil exceeds 20 ppm. The principal reason for the breadth of the range is thought to be natural, i.e. due to geological factors that produce high concentrations in a few geological locations and generally lower concentrations in others.

The amounts of mercury in crude oil presently estimated by U.S. EPA are based on data acquired for specific purposes in which mercury is problematic and likely are biased high. For example, the current EPA guidance to companies required to inventory processed material that contains mercury is that crude oil contains, on average, more than 1 ppm total mercury (http://www.epa.gov/tri/guidance.htm). More recent estimates (Wilhelm, S. M., *Env. Sci. & Tech.*, in press) place the average below 20 ppb. An accurate estimate is important in that it impacts many aspects of currently existing and anticipated regulations including the Toxic Release Inventory (Pollution Prevention Act, EPCRA), air emissions (Clean Air Act, MACT) and wastewater discharges (Clean Water Act, NPDES).

Objectives

The main objective of the project is to determine, to the extent possible within the budgetary constraints, the mean concentration and range of total mercury concentrations in crude oils processed in the U.S. In addition, the uncertainty in the assigned mean will be quantified by examination of the variability in measured concentrations that are superimposed on the natural geologic variance. These variations include those produced by sampling procedures, by analytical methods and by sample heterogeneity.

Assigning any significance to hazards or detrimental processing impacts associated with mercury in crude oil is not an objective of the study. The data to be acquired are intended only to provide a better understanding of the total amount of mercury in crude oil processed in the U.S., relative to other better quantified sources, and to identify those areas in which additional research efforts may be required. This will be a blind study, meaning that the crude oil sources (foreign or domestic), field or refinery identities and sample locations will not be made available to the U.S. EPA. Statistical weighting of concentrations to processed volumes will be accomplished on a regional basis (country or continent).

Technical Approach

Three main tasks have been identified that will provide the information necessary to accomplish project objectives. In Task 1, total mercury concentrations in formulated hydrocarbon liquids and in natural crude oils will be measured by three different analytical methods. The analytical methods selected are chemical extraction (Bloom, N. S. *Fresenius' J. Anal. Chem.*, **2000**, 366, 438), combustion/trap (Liang, L.; Lazoff, S.; Horvat, M.; Swain, E.; Gilkeson, J. *Fresenius' J. Anal. Chem.*, **2000**, 367, 8), and instrumental neutron activation (Musa, M.; Markus, W.; Elghondi, A.; Etwir, R.; Hannan, A.; Arafa, E. *J. Radioanal. Nucl. Chem.*, **1995**, 198:1, 17). The test matrix is designed to assist understanding of analytical variations and matrix/species effects in measured total mercury concentrations.

In Task 2, concentrations of total mercury in selected crude oil streams will be measured so as to gain information on sampling variations and the natural variability of mercury in crude oils delivered to U.S. refineries. A small number of well-defined streams will be sampled and analyzed over time to allow quantification of variance attributable to sample age, heterogeneity and methodology.

In Task 3, total mercury concentrations in a statistically derived crude oil sample ensemble will be measured. Samples will be obtained from fields, tankers, pipelines, refinery tankage and the strategic petroleum reserve. The ensemble will be constructed to allow calculation of the mean and range of concentrations of total mercury in crude oil. While it is recognized that the available sample group may not be completely representative of all oil processed in the U.S., every effort will be made to obtain a broad cross section of sample locations and to avoid biases in the selection process. To calculate an average concentration of mercury in crude oil processed yearly in the U.S., concentration data for particular streams will be weighted to the volume of processed oil they correspond to.

Participation

U.S. EPA and API are seeking participation in the project from interested crude oil producing and refining companies. Participation would consist of donation of crude oil samples to the analytical effort. In exchange for participation, companies will receive a detailed description of the sampling and analytical procedures and the raw data generated in the course of the project. In addition, participating companies will have opportunity to provide technical direction to the project. Companies or laboratories wishing to participate in the analytical exercise are welcome to the extent of sample availability. The compiled and blinded data will be publicly available at the completion of the project (2003).

Companies that are members of API should contact Karin Ritter (ritterk@api.org) to participate within the API framework. Companies or organizations not belonging to API should contact Mark Wilhelm (smw@hgtech.com) for project details and requirements. Additional background information may be obtained from David Kirchgessner at U.S. EPA (kirchgessner.david@epamail.epa.gov).

Budget and Schedule

U.S. EPA has budgeted $200 K for the project and API may contribute additional funds in 2002. Participating companies or organizations that are not members of API are requested to pay a nominal (optional) fee of US$ 2,000.00 to cover managerial and reporting costs. The project will initiate on November 1, 2001, and conclude in second quarter 2003.

Mercury in Crude Oil

Table 1 – THg in Crude Oil by INAA *(7)*

Source	Amount (ppb)	SD (ppb)	Notes
California	114	2.8	Detection Limit = 4 ppb
California	81	1.9	
California	88	3.0	
California	29,688	103.9	Cymric
California	78	2.4	
Libya	2,079	11.9	
Libya	62	5.1	
Libya	75	1.7	
Louisiana	23	1.8	
Wyoming	77	3.4	
Mean	3,200		Range 23 – 30,000 ppb

Table 2 - THg in Alberta Crude Oils *(9)*

Strata	Number of Samples	Number Above DL	High (ppb)	Low (ppb)	Mean* (ppb)	Median (ppb)	SD	Detection Limit (ppb)
Upper Cretaceous	21	11	202	DL	17.6	2.5	46.0	2
Lower Cretaceous	18	7	138	DL	17.1	1	38.1	2
Jurassic	3	0	1	DL	1	1		2
Triassic	4	2	6	DL	3	2.5	2.4	2
Carboniferous	8	4	19	DL	5	1.5	6.3	2
Devonian	36	13	399	DL	36	1	92.5	2
Total	**86**	**38**	**399**	**DL**	**21.9**	**1**	**63.6**	

** calculated assuming < DL = 1 ppb*

Table 3 - THg in Crude Oil and Gas Condensates

Reference	Type	Number of Samples	Range (ppb)	THg (ppb) mean	SD	Notes
Musa *(12)*	Crude Oil	7	0.1 - 12	3	4.2	Libyan
Liang *(13)*	Crude Oil	11	1 – 7	4	1.0	
Bloom *(14)*	Crude Oil	76	NR*	1,505	3,278	All
Bloom (14)	*Crude Oil*	*39*	*NR*	*1.2*	*1.5*	*Lowest 39 samples*

Bloom (14)	*Crude Oil*	*37*	*NR*	*3,009*	*4,140*	*Highest 37 samples*
Tao *(15)*	Crude Oil	1		<1		Asia
Olsen *(16)*	Condensate	4	NR	15		
Bloom *(14)*	Condensate	18	NR	3,964	11,665	Lowest 8 samples
Bloom (14)	*Condensate*	*8*	*NR*	*20*	*20*	*Lowest 8 samples*
Bloom (14)	*Condensate*	*10*	*NR*	*7,113*	*15,240*	*Highest 10 samples*
Shafawi *(17)*	Condensate	5	9 - 63	30	18.6	S.E. Asia
Tao *(15)*	Condensate	7	15 - 173	40		Asian

** NR – not reported*

Table 4 – Recent THg in Crude Oil Data

Reference	**Type**	**Number of Samples**	**Range (ppb)**	**Mean THg (ppb)**	**SD**	**Notes**
Magaw *(18)*	Crude Oil	2		<10		Middle east
Magaw *(18)*	Crude Oil	4		<10		Africa
Magaw *(18)*	Crude Oil	11	ND – 1,560	146		North America 1,560 Cymric
Magaw *(18)*	Crude Oil	4		<10		Asia
Magaw *(18)*	Crude Oil	4		<10		South America
Magaw *(18)*	Crude Oil	1		<10		North Sea
Morris *(19)*	Crude Oil	7	1.0 –3.2	1.7		Africa
Morris *(19)*	Crude Oil	2	2.4 – 5.7	4.3		Middle East
Morris *(19)*	Crude Oil	1	1.9	1.9		Canada
Morris *(19)*	Crude Oil	4	2.5 – 9.3	5.0		North Sea
Morris *(19)*	Crude Oil	2	0.1 – 2.7	1.4		Mexico
Morris *(19)*	Crude Oil	6	0.8 – 12.3	5.2		South America
Morris *(19)*	Crude Oil	1	3.1	3.1		Mixed
EC *(20)*	Crude Oil	11		<15		U.S.
EC *(20)*	Crude Oil	2		<15		Canada
EC *(20)*	Crude Oil	2		<15		Mexico
EC *(20)*	Crude Oil	3		<15		South America
EC *(20)*	Crude Oil	2		<15		North Sea
Duo *(21)*	Crude Oil	8	<2 - 9	1.6		Canadian Imports

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Characterization and Source Identification of an Unknown Spilled Oil Using Fingerprinting Techniques by GC–MS and GC–FID

This article describes a case study in which forensic chemical analyses were conducted to determine the liability for the release of an unknown petroleum product into a river. The source of the spilled oil was identified using gas chromatography with mass spectrometry and flame ionization detection by comparing the chemical fingerprints of aliphatic, aromatic, biomarker, and total petroleum hydrocarbon fractions. The source was further confirmed by determining and comparing the diagnostic ratios of a series of source-specific marker compounds, in particular, isomers of polycyclic aromatic hydrocarbons (PAHs) and alkylated series of PAHs within the same alkylation groups. From the chemical fingerprinting and data interpretation results, the authors concluded that the oil spilled was diesel fuel, that the fuel had been only slightly weathered since its spill, that the suspected diesel was clearly demonstrated to be the source of the spilled oil, and that the spilled diesel was relatively fresh and the period since the spill was no more than several days.

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Oil spills were reported and sampled on 17 and 23 March 1998 at a sewer outlet flowing into the Lachine Canal in Quebec, Canada. Following the accident, a diesel fuel, which was suspected to be the source of the spill, was taken from a reservoir at a pumping station located at the corner of Clement and St. Patrick Streets in Lachine, Quebec. To determine the environmental impact of the unknown oil, the responsibility for the spilled oil cleanup, and the legal liability, the Oil Laboratory of Emergencies Science division, Environment Canada, was asked to characterize the oil and determine whether the oil in the Lachine Canal was from the reservoir at the pumping station.

In response to the oil spill identification and specific site investigation needs, we recently focused our attention on the development of flexible, tiered analytical approaches that facilitate the detailed compositional analysis by gas chromatography–mass spectrometry (GC–MS), gas chromatography–flame ionization detection (GC–FID), and other analytical techniques to determine individual petroleum hydrocarbons in a complex mixture of compounds (1–5). A variety of diagnostic ratios, especially ratios of alkylated polycyclic aromatic hydrocarbons (PAHs) and biomarker compounds — such as tricyclic terpanes, C_{29} αβ and C_{30} αβ hopanes, and C_{27}–C_{29} (20*S* + 20*R*) ααα and αββ steranes — have been proposed during the past decade for identifying oil sources, monitoring weathering and biological degradation processes, and interpreting chemical data from oil spills.

High-molecular-mass PAHs and biologic markers are degradation-resistant and can be highly source-specific. Their presence can make differentiation among similar contaminants possible. Historically, identification of and differentiation between similar oils and refined products by standard U.S. Environmental Protection Agency (EPA) methods have been hampered by analytical limitations (5,6). Therefore, many EPA and American Society for Testing and Materials (ASTM) methods have been modified recently to improve specificity and sensitivity for measuring spilled oil and petroleum products in soils and waters. These modified methods represent a clear advance beyond the standard EPA methods because they can provide far more information that is directly useful for the characterization and quantification of oil hydrocarbons and for oil spill identification and differentiation.

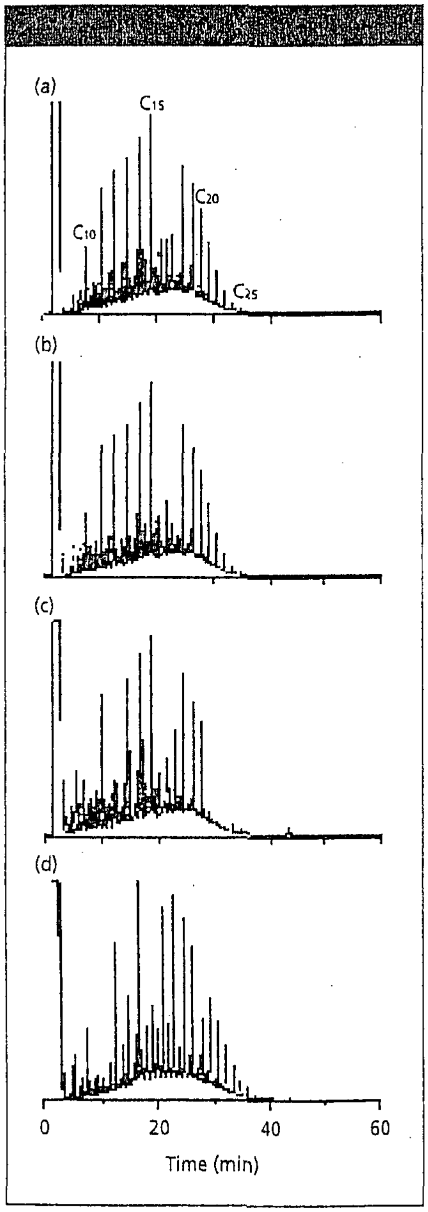

Figure 1: GC–FID chromatograms for the total petroleum hydrocarbon analysis of the Quebec spill samples (a) 2964, (b) 2965, and (c) 2966 and (d) the number 2 diesel.

In this article, we report how the oil spilled into the Lachine Canal in 1998 was accurately identified by hydrocarbon distribution pattern recognition and determination of diagnostic ratios of source-specific marker compounds.

Experimental

Sample preparation: After removing the custody seal number from the oil–water sample bottles, we took appropriate amounts of oil (approximately 0.4 g) from the well-separated top layer (with some clear water on the bottom layer) of spill samples numbered 2964 and 2965, dissolved them in hexane, and made them up to 5.00 mL. The suspected source diesel fuel (sample 2966) and the Emergencies Science Division reference number 2 diesel were weighed accurately and dissolved directly in hexane at a concentration of approximately 80 mg/mL.

We spiked an aliquot of oil-in-hexane solution with 200 µL of deuterated surrogate mixture containing 2 µg each of four deuterated PAHs (acenaphthene-d_{10}, phenanthrene-d_{10}, benz[*a*]anthracene-d_{10}, and perylene-d_{12}) and quantitatively transferred it to a preconditioned 3.0-g silica gel column topped with 1 cm of anhydrous sodium sulfate for sample cleanup and fractionation. Hexane (12 mL) and 50% benzene in hexane (15 mL) were used to elute the saturated and aromatic hydrocarbons, respectively. Half of the hexane fraction (labeled F1) was used to analyze aliphatics, *n*-alkanes, and biomarker terpane and sterane compounds; half of the 50% benzene fraction (labeled F2) was used to analyze alkylated homologous PAHs and other EPA priority unsubstituted PAHs; the remaining halves of the hexane fraction and 50% benzene fraction were combined into a fraction (labeled F3) and used to determine the total GC-detectable petroleum hydrocarbons and the unresolved complex mixture of hydrocarbons. These three fractions were concentrated under a stream of nitrogen to appropriate volumes, spiked with internal standards (5-α-androstane for GC-total petroleum hydrocarbon and *n*-alkane determination, terphenyl-d_{14} for PAH analysis, and C_{30}-ββ-hopane for biomarker analysis), and then adjusted to accurate preinjection volumes (1.0 mL) for GC–MS and GC–FID analyses.

Capillary GC and GC–MS: We analyzed for *n*-alkane distribution and total petroleum hydrocarbons using a model 5890 gas chromatograph equipped with a flame-ionization detector and a model 7673 autosampler (all from Agilent Technologies, Wilmington, Delaware). Analyses of PAH and biomarker compounds were performed on a model 5890 gas chromatograph equipped with a model 5972 mass-selective detector (Agilent Technologies). System control and data acquisition were achieved with a model G1034C MS ChemStation (DOS series, Agilent Technologies). For detailed chromatographic conditions, analysis quality control, and quantification methodology, see references 7 and 8.

Results and Discussion

Determination of hydrocarbon groups and spill-oil type identification: Oil and oil-product types often can be identified by their GC profiles, carbon range, and major component distribution patterns, especially during the early stages of an oil spill. Figure 1 shows the GC–FID chromatograms for a total petroleum hydrocarbon analysis of the F3 fraction. GC–FID chromatograms provide a descriptive picture or fingerprint of the major oil components and information about the weathering extent of the spilled oil. Figure 1 clearly demonstrates that the GC chromatograms of spilled oils are dominated by the resolved hydrocarbons, which are composed largely of *n*-alkanes and isoprenoids. The *n*-alkanes of the spill samples mainly distribute in a carbon range from *n*-C_8 to *n*-C_{25} (much narrower than the carbon range from *n*-C_8 to *n*-C_{41} for crude oils) with maxima being approximately *n*-C_{14}–*n*-C_{18}. The samples also contain a large amount of unresolved complex mixture of hydrocarbons, which are nearly symmetrical and in the center of the chromatograms. These kinds of chemical composition features are typical characteristics of relatively fresh diesel fuels.

Table I summarizes the hydrocarbon group analysis results. In addition to the GC–total petroleum hydrocarbon and total saturate values, Table I lists the ratios of total saturates–total petroleum hydrocarbon and resolved peaks–total petroleum hydrocarbon, diagnostic ratios of C_{17}–pristane, C_{18}–phytane, and pristane–phytane. Figure 2 quantitatively depicts *n*-alkane distributions.

The major chemical composition features of total petroleum hydrocarbon and saturate hydrocarbons in the spill samples can be summarized as follows: The GC–total petroleum hydrocarbon and concentrations of the total *n*-alkanes, including pristane and phytane (*n*-C_8–*n*-C_{27}) were determined to be greater than 830 mg/g and approximately 130 mg/g oil, respectively, which was significantly higher than the corresponding values for crude oils. The ratios of GC-resolved peaks to total GC area were determined to be 0.27 and 0.30 for F1 and F3, respectively, which also was much higher than for crude oils. This parameter is a useful indicator of the degree of oil degradation caused by preferential biodegradation of resolved hydrocarbons during weathering processes (6,9). In general, the lower these ratios and the lower the concentrations of *n*-alkanes are, the greater the weathering and degradation of the residual oil in a sample. The spill samples showed nearly identical GC chromatograms and *n*-alkane fingerprints as the suspected source diesel sample number 2966. More importantly, the relative ratios of C_{17}–pristane, C_{18}–phytane, and pristane–phytane determined for the spill samples 2964 and 2965 were exactly the same as those for the suspected source diesel. All of this evidence directed us toward the conclusion that the spill samples collected from the Lachine Canal most probably came from the pumping station. We observed some loss of the light end *n*-alkanes (carbon numbers lower than C_{11}) compared with the suspected source oil, which indicated the spilled oil was only slightly weathered after the spill incident and the chemical composition of aliphatic components had not undergone significant alteration. The number 2 diesel demonstrated a different GC chromatographic profile and *n*-alkane distribution profile, in particular, significantly different ratios of C_{17}–pristane, C_{18}–phytane, and pristane–phytane (Table I) from the spill samples.

Table I: Hydrocarbon group and total petroleum hydrocarbon analysis results of the spill samples

Sample	#2964	#2965	#2966	Number 2 Diesel
GC–total petroleum hydrocarbons (mg/g oil)	861	828	865	841
Total saturates (mg/g oil)	723	654	729	705
Saturates–total petroleum hydrocarbons (%)	84	81	84	84
Resolved peaks–GC–total petroleum hydrocarbons	0.27	0.27	0.27	0.32
Resolved saturates–total saturates	0.30	0.30	0.31	0.35
Total *n*-alkanes (mg/g oil)	135	122	133	156
C_{17}–pristane	2.73	2.70	2.76	5.37
C_{18}–pristane	1.72	1.72	1.75	2.74
Pristane–phytane	0.87	0.88	0.89	0.76

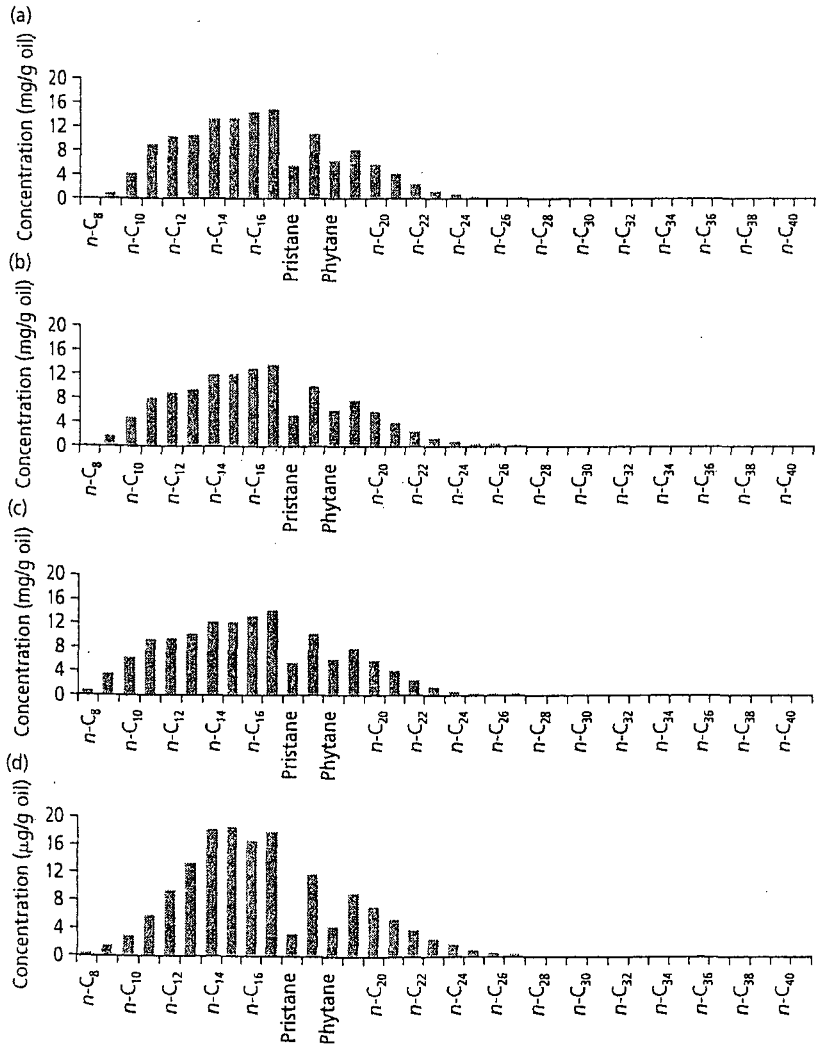

Figure 2: *n*-Alkane distributions of the Quebec spill samples (a) 2964, (b) 2965, and (c) 2966 and (d) the number 2 diesel.

Distribution of oil-characteristic alkylated PAH and biomarker compounds: In general, PAH compounds, especially the high molecular mass PAHs, are relatively stable and therefore can be useful as diagnostic constituents of petroleum. In recent years, the use of oil-characteristic alkylated PAH homologues as environmental fate indicators and oil source specific markers has increased significantly (1–7).

Figure 3 shows the distribution of alkylated PAHs and the other 15 EPA priority unsubstituted PAHs among the four samples. We determined the sum of the five target alkylated PAHs to be 53,000–59,700 µg/g for the spill samples, which is far higher than that for most crude oils and oil products. By contrast, the sum of the five target alkylated PAHs in the number 2 diesel was determined to be 26,313 µg/g of oil, which is approximately one-half of the PAH concentration of the spilled fuel.

GC–MS measurements show that the aromatic fraction of the spilled oil contained a small amount of benzene, toluene, ethylbenzene, and the xylene isomers — collectively called BTEX — and other lighter alkylbenzene compounds, as well as the main components alkylated naphthalene, phenanthrene, fluorene, and dibenzothiophene homologues (76, 14, 7, and 3% of the total of the five target PAH homologues). The alkyl naphthalene series was the most abundant among the five target alkylated PAH series. The alkylated chrysene series was the least abundant (only 12–14 μg/g of oil, less than 0.0003% of the total alkylated PAHs), and no C_3-chrysenes were detected, which resulted in the relative ratios of chrysene series to the other four PAH series approaching zero. Among the other EPA priority PAHs, the dominance of two- and three-ring PAHs is apparent. The concentrations of five- and six-ring PAHs were extremely low, and most of them were less than the detection limits.

The PAH analysis results clearly demonstrate that the PAH distribution patterns of spill samples are nearly identical to the suspected source diesel but significantly different from the number 2 diesel. The sulfur-containing PAHs, alkylated dibenzothiophenes, in the number 2 diesel are noticeably more abundant than in the spill samples, resulting in a significantly higher C_2D/C_2P–C_3D/C_3P value (1.84:1.51 as compared with 0.22:0.35 for the spill samples, see Table II). The slightly lower concentrations of naphthalene in the spill samples than in the suspected source fuel further suggested that only slight weathering of the spilled oil had occurred.

Figure 4 shows GC–MS distribution profiles of the highly degradation-resistant terpane and sterane compounds at *m/z* 191 and 217 for the suspected source oil and the number 2 diesel, respectively. The spill samples 2964 and 2965 showed identical GC–MS distribution patterns of biomarkers as that of the suspected source diesel. Figure 4 clearly indicates that the spilled oil contains very small amounts (<10 μg/g) of low molecular weight biomarker compounds, including C_{19}–C_{24} tricyclic terpanes and $C_{20}H_{34}$ ααα, $C_{21}H_{36}$ αββ, and $C_{22}H_{38}$ αββ steranes. No tetracyclic and pentacyclic biomarkers that have carbon numbers greater than C_{25} were detected. Obviously, the refining process had removed high molecular weight PAHs and biomarkers from the crude oil feed stock. The number 2 diesel contains biomarker compounds as well, but has a different distribution profile from the suspected source diesel and demonstrates much higher — approximately twofold — biomarker concentrations. Also, we detected additional C_{27} diasteranes and C_{27} (20*R* + 20*S*) cholestanes in the number 2 diesel but found none in the spilled oil.

Determination of diagnostic ratios of source-specific compounds: Using various diagnostic ratios complements existing methods of oil characterization but has its own distinct advantages (5). The distribution of the selected compounds is source-specific; that is, their distribution and relative ratios often differ from oil to oil. The parameters determined are relative ratios, and they are subject to little interference from absolute concentration fluctuations of individual compounds; therefore, they can

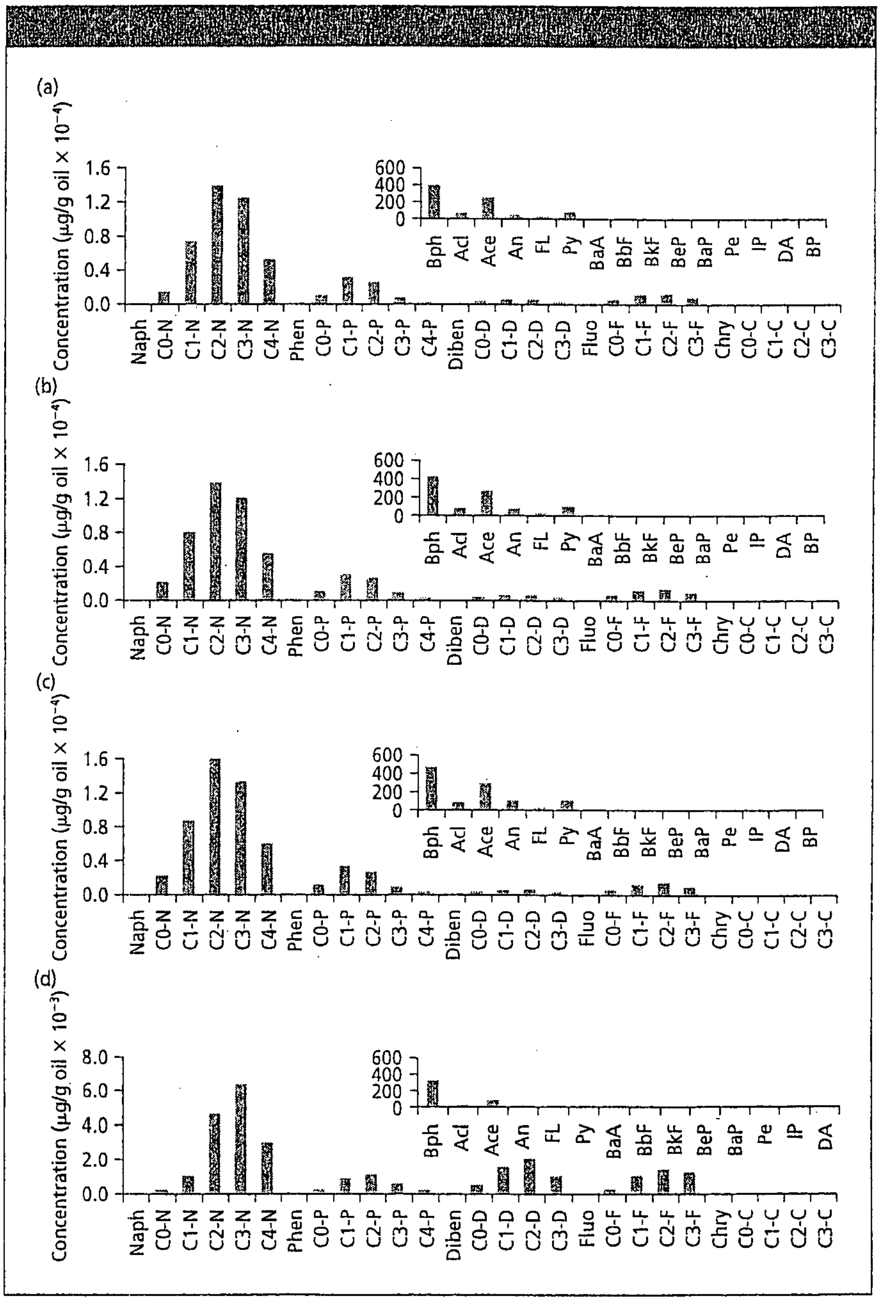

Figure 3: Alkylated PAH fingerprints of the Quebec spill samples (a) 2964, (b) 2965, and (c) 2966 and (d) the number 2 diesel. N, P, D, F, and C represent naphthalene, phenanthrene, dibenzothiophene, fluorene, and chrysene, respectively; 0, 1, 2, 3, and 4 represent carbon numbers of alkyl groups in alkylated PAH homologues. The insets are enlarged fingerprints of the other EPA priority PAHs. The abbreviations Bp to BgP represent biphenyl, acenaphthylene, acenaphthene, anthracene, fluoranthene, pyrene, benz[*a*]anthracene, benzo[*b*]fluoranthene, benzo[*k*]fluoranthene, benzo[*e*]pyrene, benzo[*a*]pyrene, perylene, indeno[1,2,3-*cd*]pyrene, dibenz[*a,h*]anthracene, and benzo[*ghi*]perylene, respectively. For clarity, a different *y*-axis scale is used for the number 2 diesel.

more truly reflect differences of the target compound distributions between samples.

Table II summarizes the diagnostic ratios of source-specific hydrocarbons for the spill samples. Table III and GC–MS analysis results reveal the following: The relative distribution of the alkyl naphthalenes, phenanthrenes, dibenzothiophenes, and fluorenes in their alkylated homologous families was nearly identical for the spill samples and the suspected source diesel. The double ratios of C_2-dibenzothiophene/C_2-phenanthrene–C_3-dibenzothiophene/C_3-phenanthrene also were very close to each other (0.21:0.34 to 0.22:0.36) among these three samples.

Isomeric distributions of 4-, 2-/3-, and 1-methyldibenzothiophene were exactly the same for the spill samples and the suspected source diesel (1.0:0.78:0.24). These characteristic ratios have been very useful markers for differentiating crude and weathered oils (5,10). Furthermore, this phenomenon was mirrored by the near identity (1.51 to 1.54) in the relative isomeric distribution of (3– + 2-methylphenanthrenes) to (4-/9– + 1-methylphenanthrenes). Wang and Fingas (10) demonstrated that the isomeric distribution within these alkylated PAH isomer groups *exhibits consistency in relative ratios* during physical weathering of oils. However, if biodegradation occurs, these isomeric PAH compounds exhibit unique microbial degradation patterns different from changes caused by physical weathering in both concentrations and relative distributions (9). The corresponding relative distribution values determined for the number 2 diesel were different from those of the spill samples (Table IV).

The spill samples and the suspected source diesel showed nearly identical ratios of biomarker terpanes C_{23}/C_{24} (2.4 to 2.5), and the number 2 diesel showed significantly smaller ratios of C_{23}/C_{24} (1.5, see Table II).

Conclusions

This article described an analytical approach using hydrocarbon distribution pattern recognition and diagnostic ratios of source-specific marker compounds for the characterization of chemical composition and source identification of the spilled oil from the Lachine Canal. The GC fingerprinting and data interpretation results indicated that the spilled oil was a diesel fuel. The spilled diesel was weathered only slightly since its spill, evidenced by high ratio values of the resolved peaks to the total GC area, high concentration of *n*-alkanes, existence of BTEX compounds, and almost unchanged ratios of C_{17}–pristane and C_{18}–phytane. The suspected diesel collected from the pumping station clearly was demonstrated to be the source of the spilled oil. The reference number 2 diesel showed significantly different chemical compositions and had no relation to the spilled oil. Finally, the spilled diesel was relatively fresh, and the time since being spilled was estimated to be no more than several days.

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Table II: Target PAH diagnostic ratios of source-specific marker compounds

Sample	#2964	#2965	#2966	Number 2 Diesel
C_2-dibenzothiophene/C_2-phenanthrene–C_3-dibenzothiophene/C_3P	0.22:0.36	0.21:0.34	0.22:0.35	1.84:1.51
4-:2-/3-:1-methyldibenzothiophene	1:0.78:0.24	1:0.78:0.24	1:0.78:0.24	1:0.70:0.13
(3– + 2- methylphenanthrene)/(4-/9– + 1-methylphenanthrene)	1.52	1.51	1.54	1.07
C_{23}-terpane/C_{24}-terpane	2.40	2.45	2.43	1.52

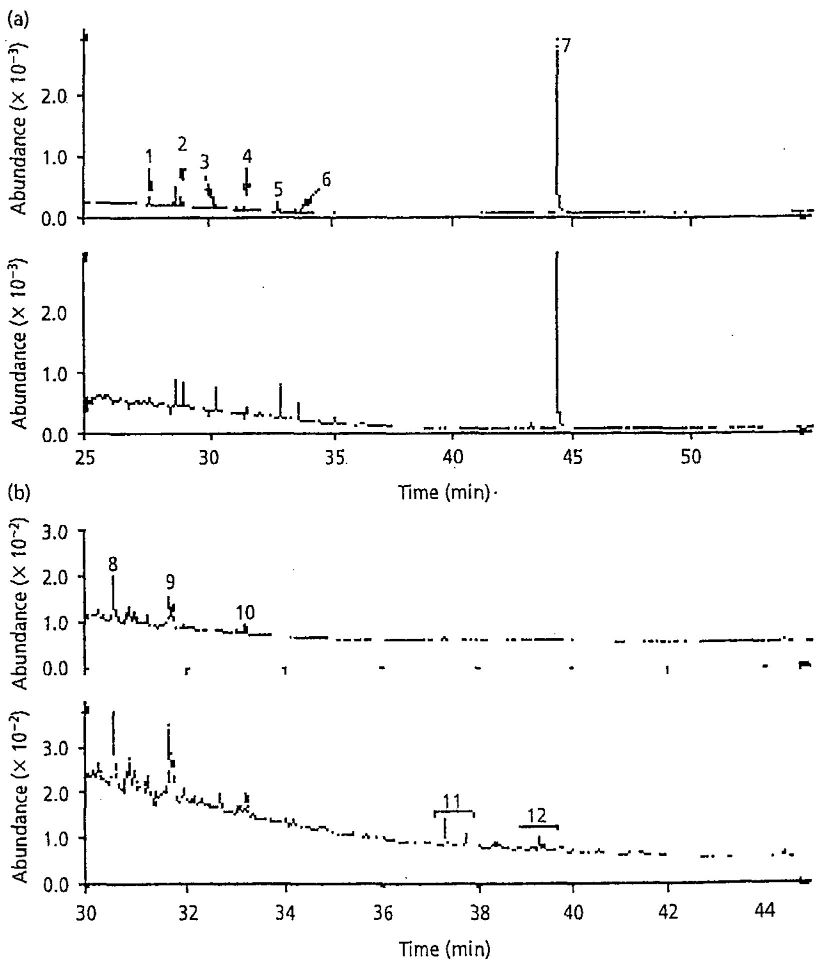

Figure 4: Comparison of distribution of biomarker (a) terpanes (*m/z* 191) and (b) steranes (*m/z* 217) in the suspected spill source oil (top chromatogram in [a] and [b]) and the number 2 diesel (bottom chromatogram in [a] and [b]). Peaks: 1 = $C_{19}H_{34}$, 2 = $C_{20}H_{36}$, 3 = $C_{21}H_{38}$, 4 = $C_{22}H_{40}$, 5 = $C_{23}H_{42}$, 6 = $C_{24}H_{44}$, 7 = internal standard, 8 = $C_{20}H_{34}$, 9 = $C_{21}H_{36}$, 10 = $C_{22}H_{38}$, 11 = diasteranes, 12 = C_{27} steranes.

Table III: Relative distribution of PAHs within their alkylated families

Sample	#2964	#2965	#2966	Number 2 Diesel
Napthalenes				
C_0-naphthalene	0.04	0.05	0.05	0.02
C_1-naphthalene	0.18	0.19	0.19	0.14
C_2-naphthalene	0.35	0.33	0.35	0.35
C_3-naphthalene	0.31	0.29	0.29	0.34
C_4-naphthalene	0.13	0.13	0.13	0.14
Sum	1.00	1.00	1.00	1.00
Phenanthrenes				
C_0-phenanthrene	0.14	0.13	0.14	0.09
C_1-phenanthrene	0.42	0.41	0.41	0.32
C_2-phenanthrene	0.33	0.33	0.33	0.33
C_3-phenanthrene	0.09	0.10	0.10	0.19
C_4-phenanthrene	0.02	0.02	0.02	0.07
Sum	1.00	1.00	1.00	1.00
Dibenzothiophenes				
C_0-dibenzothiophene	0.19	0.19	0.19	0.12
C_1-dibenzothiophene	0.32	0.32	0.32	0.29
C_2-dibenzothiophene	0.33	0.34	0.33	0.40
C_3-dibenzothiophene	0.16	0.15	0.16	0.19
Sum	1.00	1.00	1.00	1.00
Fluorenes				
C_0-fluorene	0.15	0.14	0.14	0.07
C_1-fluorene	0.29	0.29	0.29	0.23
C_2-fluorene	0.35	0.35	0.35	0.38
C_3-fluorene	0.21	0.22	0.22	0.31
Sum	1.00	1.00	1.00	1.00
Chrysenes				
C_0-chrysene	0.51	0.51	0.49	0.28
C_1-chrysene	0.32	0.30	0.32	0.39
C_2-chrysene	0.17	0.19	0.19	0.23
C_3-chrysene	0.00	0.00	0.00	0.10
Sum	1.00	1.00	1.00	1.00

Table IV: Target PAH quantitation results

Sample	#2964	#2965	#2966	Number 2 Diesel
Alkylated PAH homologous series (μg/g oil)				
Naphthalenes (C_0–C_4)	39,988	40,950	45,795	13,819
Phenanthrenes (C_0–C_4)	7,614	7,356	8,001	3,701
Dibenzothiophenes (C_0–C_3)	1,656	1,607	1,717	5,714
Fluorenes (C_0–C_3)	3,824	3,741	4,184	3,018
Chrysenes (C_0–C_3)	14	12	14	61
Sum of the alkylated PAHs	53,123	53,666	59,711	26,313
Other EPA priority PAHs (μg/g oil)	832	937	1,066	400
Total target PAHs (μg/g oil)	53,955	54,603	60,777	26,713

(2) D.S. Page, P.D. Boehm, G.S. Douglas, and A.E. Bence, in *Exxon Valdez Oil Spill: Fate and Effects in Alaska Waters*, P.G. Wells, J.N. Butler, and J.S. Hughes, Eds. (ASTM, Philadelphia, Pennsylvania, 1995), pp. 41–83.

(3) T.C. Sauer and P.D. Boehm, "Technical Report Series 95-032," Marine Spill Response Corp. (Washington, D.C., 1995).

(4) A.E. Bence, K.A. Kvenvolden, and M.C. Kennicutt II, *Organ. Geochem.* 24, 7–42 (1996).

(5) Z.D. Wang, M. Fingas, and D. Page, *J. Chromatogr.* 843, 369–411 (1999).

(6) G.S. Douglas and A.D. Uhler, *Environ. Test. Anal.* May/June, 46–53 (1993).

(7) Z.D. Wang, M. Fingas, and G. Sergy, *Environ. Sci. Technol.* 28, 1733–1746 (1994).

(8) Z.D. Wang, M. Fingas, and K. Li, *J. Chromatogr. Sci.* 32, 361–366 (1994).

(9) Z.D. Wang, M. Fingas, S. Blenkinsopp, G. Sergy, M. Landriault, L. Sigouin, J. Foght, K. Semple, and D.W.S. Westlake, *J. Chromatogr.* 809, 89–107 (1998).

(10) Z.D. Wang and M. Fingas, *Environ. Sci. Technol.* 29, 2842–2849 (1995). ■

Texaco USA: Overall Grade D

Location: Fidalgo Bay, two miles east/southeast of Anacortes.

Operations: The refinery refines approximately 142, 000 barrels of crude oil per day to produce gasoline, diesel fuel, and other petroleum-based products.

Discharge: Two to six million gallons of effluent per day is treated via oil water separation, primary, and secondary treatment. The refinery's wastewater outfall extends 5000 from the shore in a north/northwesterly direction into Fidalgo Bay.

Receiving water: Fidalgo Bay is classified as Class A marine water.

Major permit limits and conditions

The permit issued in 1990 established limits for Biological Oxygen Demand (BOD), Chemical Oxygen Demand (COD), Total Suspended Solids (TSS), oil and grease, phenolic compounds, ammonia, sulfide, chromium, fecal coliform and pH. The permit also has an acute biomonitoring limit. The permit also required a storm water runoff study, a spill control plan, a cyanide study, acute and chronic biomonitoring studies, a chemical analysis of influent and effluent, a dioxin and furan study and sediment monitoring studies. Texaco is allowed to meet water quality-based standards at the edge of a dilution zone around their discharge.

Compliance with permit conditions: D

Texaco submitted all of their studies and reports on time. They were fined $7000 in 1993 for a ballast water spill, and $20,000 for an oil spill in 1991.

Compliance with permit limits: F

Texaco has been fined four times in the past six years for water quality violations. These violations were for exceeding their numeric limits for total suspended solids, fecal coliform, oil and grease, and biological oxygen demand. The last one, for biological oxygen demand, occurred in June 1996. Texaco was fined a total of $12,000 for these violations.

Oil and grease discharge: 5

From August 1995 to July 1996, Texaco discharged an average of 156 pounds of oil and grease per day. This was 74% of their permit limit. This equates to 11.0 pounds of oil and grease discharged for every 10,000 barrels of crude oil refined.

Current status of permit compliance: B

Texaco was fined once in 1995 and once in 1996 for permit violations. Texaco is spending 11 million dollars to significantly up-grade their waste water treatment system in response to these violations.

Concerns about effluent

- Monitoring conducted during the last six years has shown that ammonia, cadmium, chlorine, copper, cyanide, lead, mercury, nickel, selenium, and zinc have exceeded water quality standards in the final effluent.
- The dioxin and furan study found up to 7000 picograms per liter of furan and 310 picograms per liter of dioxin in the waster water from the catalytic reformer unit.
- Several of the acute biomonitoring test done over the last five years have shown high levels of mortality, and chronic tests have shown toxic effects.

Major future considerations

The poor performance of Texaco's treatment system is resulting in them upgrading the system. They intend to spend approximately $11 million over the next year for this upgrade.

When Texaco's permit is re-issued it should

- require them to prove they have AKART in place for ammonia, cadmium, chlorine, copper, cyanide, lead, mercury, nickel, selenium, zinc, dioxins and furans;
- contain improved biomonitoring limits; and
- require sediment studies and receiving water studies to fully characterize the impact of the effluent on the environment.

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This report was published in 1996.

Location: http://www.pugetsound.org/p2/reportfolder/ch3e.html
Contact: webster@pugetsound.org
Credits

Petrogenic and Biogenic Sources of N-Alkanes off San Diego, California

Kim Tran, Charlie C. Yu, Eddy Y. Zeng

In a previous article (*Compositional Indices of Polycyclic Aromatic Hydrocarbon Sources off San Diego, California*, this annual report), we utilized the compositional patterns associated with polycyclic aromatic hydrocarbon (PAH) assemblages to identify and assess the sources of hydrocarbon inputs into the coastal marine environment off San Diego. Samples collected from a variety of media, including effluents from the Point Loma Wastewater Treatment Plant (PLWTP), Tijuana River (TJR) runoff, sea surface microlayer, sediment, and sediment trap materials were analyzed to obtain collective information. In this article, the compositional patterns and molecular indices of aliphatic hydrocarbons (AHs) determined in these samples were used to further identify the petrogenic and biogenic sources of hydrocarbons. Attempts were also made to estimate the relative contributions of hydrocarbons from various point sources (wastewater discharge, runoff, etc.), as well as to understand the dynamics of physical, geochemical and biochemical processes affecting the organic contaminants during their residence in the marine environment.

In the past, a great deal of attention has been focused on the distributions of PAHs, mainly due to the potential carcinogenic, mutagenic, and toxic effects to a large number of invertebrates, fishes, birds, and mammals from many of these compounds (Kennish 1992). Less emphasis has been placed on AHs, particularly n-alkanes, primarily because they are relatively less harmful to many living organisms as compared to other classes of petroleum hydrocarbons (Clark 1989). However, understanding the characteristics of AHs should provide supplemental information useful to identify the sources of petroleum hydrocarbons.

While PAHs are known to be derived mainly from direct discharges, urban runoff, combustion of fossil fuels, and forest fires (Neff 1979), they are not directly produced from biological sources at significant levels (Bird and Lynch 1974, Kennish 1992). On the other hand, AHs in the estuarine and marine environments were known to be derived from both biogenic and anthropogenic sources (Clark 1989). Significant amounts of AHs can be synthesized by many biochemical processes occurring in both terrestrial and marine organisms. These biosynthesized hydrocarbons can be released into the environment by the organisms through their metabolism or decomposition upon their death.

The composition of AHs found in the marine environment is often complex, due to a combination of inputs from various sources. To discern the sources, it is necessary to distinguish the anthropogenic hydrocarbons from those derived from the biogenic sources. Petroleum, in general, contains a rather complex suite of hydrocarbons with a wide range of boiling po (National Research Council 1985). By contrast, biogenic hydrocarbons generated by biosynthetic pathways usually exhibit relatively simple patterns (Kennish 1992). Some hydrocarbon indices thus were developed and employed by researchers in an effort to identify the possible origins of the contaminants. For instance, Clark and Blumer (1967) utilized the carbon preference index (CPI) and the concentration ratio of pristane/n-C_{17} (Pri/C_{17}) to identify the possible origins of paraffins in algae and sediments collected from the northeast coast of the United States. In a similar study, Gearing *et al.* (1976) differentiated various input sources for hydrocarbons in sediments obtained from the northeast Gulf of Mexico based upon several paraffin molecular markers, including the ratios of total odd-carbon alkanes/even-carbon alkanes (C_{odd}/C_{even}), C_{17}/Pri, n-C_{18}/phytane (C_{18}/Phy), and pristane/phytane (Pri/Phy). Recently, Colombo *et al.* (1989) applied seven AH indices, including the major hydrocarbon (MH), the low/high molecular weight hydrocarbons (LMW/HMW), n-C_{16} ratio (sum of all n-alkanes/n-C_{16}), CPI, C_{17}/Pri, and C_{18}/Phy, in conjunction with the molecular indicators derived from PAH constituents to identify the sources for the organic contaminants in the Rio de La Plata Estuary, Argentina. In another recent study, Serrazanetti *et al.* (1994) found that zooplankton samples collected in the Gulf of Trieste were partially contaminated with fossil hydrocarbons as indicated by CPI values close to 1. The satisfactory results from these studies in applying the AH compositional indices to differentiate biogenic and petrogenic inputs prompted us to utilize these molecular markers to identify the possible sources of pollutants in the Southern California Bight.

MATERIALS AND METHODS

Materials

Neat individual n-alkane standards, isoprenoid hydrocarbon standards (pristane and phytane), and internal standards (nitrobenzene-d5 and chrysene-d12) were obtained from Ultra Scientific, Inc. (North Kingstown, RI). Surrogate standards (n-C12D26, n-C24D50, and n-C_{36}D74) were purchased from C/D/N Isotopes, Inc. (Quebec, Canada). Ultra resi-analyzed grade methylene chloride and hexane were obtained from J.T. Baker, Inc. (Phillipsburg, NJ). The standard solutions were all prepared in hexane.

Sample Collection and Extraction

Samples were collected in January and June 1994. Due to a contamination problem with the microlayer samples collected in January 1994, no measurements were made on these samples. Detailed information about the study site and abbreviations is given in *Compositional Indices of Polycyclic Aromatic Hydrocarbon Sources off San Diego, California* in this annual report.

Gas Chromatography/Flame Ionization Detection (GC/FID) Analysis and Quantitation

A Varian 3500 GC equipped with two flame ionization detectors and two fused silica capillary columns, J&W Scientific (Folsom, CA) DB-1 and DB-5 (60 m ′ 0.25 mm i.d., 0.25 μm film thickness), was employed for sample analyses. The DB-1 column was used for quantitation, since it provided better chromatographic separation than DB-5 (for confirmation) in this particular application. The column temperature was programmed from 70oC25 (4-min hold) to 290oC 25 (41-min hold) at a rate of 7oC$_{25}$/min. Helium was used as the carrier gas with a flow rate of 2 mL/min at 70oC$_{25}$. The total flow rate of the make-up gas (helium + nitrogen) was 20 mL/min. The flow rates of combustion gas H2 and air were 24 mL/min and 280 mL/min, respectively. Two mL of each sample was manually injected into a split/splitless injector with 1-min solvent split time. The injector was maintained at 280oC$_{25}$ and the detectors at 300oC$_{25}$.

Identification of the AHs was made by injecting a mixture of the AH standards, including pristane, phytane, and n-alkanes ranging from C_{10} to C_{36}. The concentrations of AHs were measured using the internal calibration technique. The internal standards, nitrobenzene-d5 and chrysene-d12, were introduced into the calibration standards and the final extracts prior to injection. Five levels of concentration, namely, 0.1, 0.4, 2.0, 5.0, and 10.0 μg/mL for the C_{10}-C_{29} components were chosen to establish the calibration curves. For the C_{30}-C_{36}, the corresponding concentrations in the calibration solutions were four times higher than those of C_{10}-C_{29}.

The method performance was assessed by the recoveries of surrogate standards, n-C12D26, n- C24D50, and n-C_{36}D74, spiked into the standard solutions or the samples at 2 mg/mL prior to extraction. The means ± 1 standard deviation for the recoveries of the surrogate standards in 31 samples were as follows: n-C12D26 (37.1 ± 34.6); n-C24D50 (94.8 ± 26.5); and n-C_{36}D74 (61.4 ± 30.8). The concentrations of target compounds were not corrected for the recoveries of the surrogate standards.

The method detection limits (MDLs) were determined using the procedure by Clesceri *et al.* (1989). Due to the difficulties of finding sediments with low levels of AHs, only the MDLs for aqueous samples were evaluated using distilled water. Quantitation of solid samples was also based on these MDLs. The detection limits, set slightly higher than the MDL, 50 ng/g or ng/L for C_{10}-C_{18}, pristane, and phytane, 100 ng/g or ng/L for C_{19}-C_{25}, and 400 ng/g or ng/L for C_{26}-C_{36} based on 1 g of solid or 1 L of aqueous sample.

RESULTS

PLWTP Wastewater Effluent

The chromatographic peaks of all the n-alkanes in the PLWTP effluent particulates are well resolved (Figure 1). While the AH assemblages were dominated by the n-alkane components, branched paraffins such as pristane and phytane were also detected. As previously mentioned, these isoprenoid hydrocarbons may be a diagnostic tool for identifying the possible sources of the organic contaminants. In addition, the presence of the unresolved complex mixture (UCM) in the sample suggests the presence of degraded petroleum products.

The concentrations of total AHs were higher in the particulates than in the filtrates (based on the aqueous sample volume) (Table 1). This may be attributed to the relatively low solubilities of AHs in the aqueous phase. Both particulate and filtrate samples were enriched with low molecular weight AH assemblages (Figures 2a and 2b). The total concentrations of AHs (in both particulates and filtrates) were 19.6 and 13.0 mg/L for the January and June effluents, respectively.

TJR Runoff

Similar to the PLWTP effluent samples, the TJR runoff particulate samples contained higher concentrations of alkane constituents than the filtrates and the total AH concentration was higher in the January samples (3.88 mg/L) than in the June samples (0.831 mg/L) (Table 1). The filtrates were relatively enriched with low molecular weight AHs (Figure 2c), while high molecular weight AHs were more abundant in the particulates (Figure 2d).

Microlayer

The microlayer samples, in general, contained fairly high AH concentrations, as compared to the PLWTP effluent and TJR runoff (Table 1). Among the four samples, the SDB sample had the highest AH content (1020 mg/g, dry weight) , followed by A-17 (553 mg/g, dry weight). The MTJR and R-61 samples contained almost equal amounts of AHs (211 mg/g and 195 mg/g, respectively). The AH compounds were highly concentrated in the particulate phase in all the microlayer samples. In addition, the ratio of AH concentrations between particulate and filtrate phases increased from the PLWTP effluent to TJR runoff and to microlayer.

The compositions of AHs in the microlayer samples (Figure 3) exhibited different patterns as compared to those found in the PLWTP effluent and TJR runoff (Figure 2). The microlayer particulates contained mostly AHs with C_{25} or longer alkyl chain; while the filtrate samples contained primarily low molecular weight AHs. In addition, these AH fractions are essentially dominated by the odd-carbon n-alkanes (Figure 3).

Sediments

The AH concentrations ranged from 0.1 to 1.3 mg/g in four sediment samples (Table 1), which was substantially lower than those found in PLWTP effluent, TJR runoff, and microlayer samples on a particle dry weight basis. Except for the SDB samples, all the other samples contained relatively low concentrations of short-chain AHs ($n<25$) (Figure 4). It is likely that the low-molecular weight AHs may eventually be removed by evaporation, dissolution, or biodegradation. In addition, the AH assemblages were dominated by the odd-numbered long-chain paraffins at $n>25$. While the AH compositional patterns at each sample did not reveal significant seasonal variation, the total concentrations were relatively higher in the January samples than in the June samples (Table 1; Figure 4).

The sediment samples collected from the reference station R-61 contained relatively low levels of AHs, as compared to those from the others. On the contrary, the SDB sediments had the highest total concentrations of AHs. This is likely a result of the relatively high level of waste disposal due to the maritime activities in the bay area in addition to a significant surface runoff contribution from the nearby San Diego Airport. Meanwhile, the MTJR sediments contained comparable concentrations of AHs to those in the R-61 sediments.

Sediment Trap Particulates

The sediment trap particulates collected from A-17 and R-61 contained much higher AH concentrations than those in the sediments (Table 1). The AH concentrations were quite different in the January and June samples at both the A-17 and R-61 5-m traps, apparently due to the high contents of pristane in the June samples (Figure 5).

The compositional patterns for AHs with C_{20} or longer chains (Figure 5) in the sediment trap samples are similar to those in the sediment counterparts (Figure 4). The high molecular weight components showed odd-numbered AH preference. [illegible] the particulates at the A-17 1-m traps (January 1994) showed quite different distribution patterns of lower molecular [illegible] AHs (C_{10}-C_{19}) from those in the sediments. All the sediment traps collected in June 1994 contained fairly high levels of pristane.

DISCUSSION

AH Compositional Indices

A total of eight compositional indices were determined in the samples analyzed in the present study (Table 1). The major hydrocarbon, MH, which is the alkane species with the highest concentration, is normally centered around C_{18} for specimens highly contaminated with petroleum (Clark and Finley 1973). Dominant hydrocarbons in benthic algae are generally either n-C_{15}, n-C_{17}, or n-C_{19} (Lytle et al. 1979). In terrestrial vascular plants, odd-carbon n-alkanes in the range of C_{27}-C_{31} are often the major aliphatic hydrocarbon components (Farrington and Tripp 1977, Colombo *et al.* 1989). The MH found in the PLWTP effluents was C_{18} (Figures 2a and 2b, Table 1). This is in agreement with previous findings by Eganhouse and Kaplan (1982), who reported C_{14} and C_{16} as the major n-alkanes in the PLWTP effluents in 1979. As suggested by Eganhouse and Kaplan (1982), these results indicate a possible petrogenic origin for the hydrocarbons in the effluents. The TJR runoff samples, both filtrate and particulate, showed relatively high concentrations of C_{25}, C_{27}, C_{29}, and C_{31} (Figures 2c and 2d), implying that these hydrocarbon components may have originated biogenically from terrestrial plants. AH assemblages with the similar compositional pattern have been found in the external covers of stems, leaves, flowers, and fruits (Eglington and Hamilton 1967), which can easily be carried into the river. However, the filtrate samples appeared to have a second major component in the low molecular range (Figures 2c and 2d), which may indicate some degree of contamination by petroleum products. In most microlayer, sediment, and sediment trap particulate samples, the MHs were around C_{29} or C_{31} (Table 1). This may suggest that AHs from terrestrial high plants are the dominant hydrocarbon components in the coastal marine environment off San Diego.

LMW/HMW is the concentration ratio of the n-alkane fractions with molecular weights less than or equal to C_{20}(LMW) and ^{3} C_{21} (HMW). This ratio is usually near unity in petroleum products, or in plankton and benthic algae (Lytle *et al.* 1979, Colombo *et al.* 1989) and commonly has lower values in higher plants (Colombo *et al.* 1989). LMW/HMW ranged from 0.7 to 1.1 in the PLWTP effluent samples, further verifying a petrogenic source for hydrocarbons in the PLWTP effluent. Although no firm conclusion can be drawn for the TJR runoff, the relatively low LMW/HMW values are consistent with the conclusion based on MHs, i.e., biogenic inputs derived from terrestrial plants are likely predominant sources. The lower LMW/HMW values in the January samples as compared to that of the June samples may be due to a larger amount of hydrocarbons from terrestrial plants carried into the river by the rainfalls in the winter. For the microlayer, sediment, and sediment trap samples, significantly low values of LMW/HMW found in January may have signaled a relatively high influx of decomposed organic matter derived from land plants in the previous fall. When the ocean begins to warm in the spring, the population of marine algae starts to increase (Serrazanetti *et al.* 1994). Since paraffins of either n-C_{15}, n-C_{17}, or n-C_{19} were found to be predominant in benthic algae (Clark and Blumer 1967, Youngblood *et al.* 1971), this mechanism perhaps accounted for the relatively higher values of LMW/HMW for the June samples as compared to those collected in January.

Since n-C_{16} is rarely found in biolipids (Thompson and Eglinton 1978), the C_{16} ratio, defined as sum of all n-alkanes/n-C_{16}, is usually high (i.e., 50) for biogenic materials compared to relatively low values (i.e., 15) in petroleum contaminated samples (Colombo *et al.* 1989). The C_{16} ratios are around 15 in the PLWTP effluent, relatively higher in the TJR runoff, and substantially higher in all the other samples (Table 1).

Geochemical processes produce petroleum that includes many homologous series. Adjacent members of hydrocarbons in the same homologous series often appear in the petroleum mixtures at comparable concentrations (Kennish 1992). Consequently, the concentration ratios of n-alkanes with odd- and even-numbered carbons are usually around unity. Biogenic samples, on the other hand, may exhibit different trends. For instance, the n-C_{25}, n-C_{27}, n-C_{29}, and n-C_{31} components predominate over even carbon homologues for land plants and spores (Farrington and Tripp 1977) and n-alkanes with 15, 17, 19, and 21 carbons predominate the corresponding paraffins of even carbons for marine algae, zooplankton, and phytoplankton (Clark and Blumer 1967, Blumer *et al.* 1971, Farrington and Tripp 1977). The values of CPI, defined as $2(C_{27}+C_{29})/(C_{26}+2C_{28}+C_{30})$, are all close to unity in the PLWTP effluent samples (Table 1), indicating a predominant petrogenic origin for the organic matter. CPI values in other samples, in general, range from 3 to 14, confirming biogenic inputs from terrestrial plants.

The last three indices, C_{17}/Pri, C_{18}/Phy, and Pri/Phy are related to the presence of isoprenoids in AH mixtures. In petroleum contaminated samples, the concentrations of pristane and phytane are nearly equal (Gearing *et al.* 1976, Keizer *et al.* 1978). In addition, zooplankton can convert ingested phytol to pristane, which may be the principal source of pristane found in [illegible] aquatic organisms (Blumer *et al.* 1964, Clark and Blumer 1967, Wakeham and Carpenter 1976). Thus, high concentrations of pristane may be indicative of high levels of microbial degradation. The Pri/Phy ratios for the PLWTP effluent samples collected in January are near unity, but higher in the June samples (2.8 and 3.8). The C_{17}/Pri ratio, in the range of 2.1-3.7, as found in the PLWTP effluents in the current study, are comparable to 1.7-2.2 as previously reported (Eganhouse and Kaplan 1982b). Overall, the C_{17}/Pri and C_{18}/Phy ratios are relatively higher in the PLWTP effluent and TJR runoff samples than those in the microlayer, sediment, and sediment trap samples. As will be discussed later, n-alkanes (e.g., n-C_{17} and n-C_{18}) are more likely subject to biodegradation than isoprenoids. This conclusion is corroborated by the general trend of lower C_{17}/Pri and C_{18}/Phy values in the June sediment and sediment trap samples relative to the January samples, probably due to the relatively higher level of microbial activities during the warmer months.

All the samples analyzed in the present study contained an unresolved complex mixture (UCM) as shown in the chromatogram of the PLWTP effluent particulate sample collected in June 1994 (Figure 1). UCM, composed of cyclic and branched alkanes, is known to resist microbial degradation more effectively than n-alkanes and thus has a greater tendency to remain in the environment after n-alkanes have degraded (Lee 1976, Lytle et al. 1979). Although UCM alone may not be sufficient in confirming the presence of petroleum products (Keizer *et al.* 1978), additional evidence such as the presence of pristane and phytane with relatively low values of C_{17}/Pri and C_{18}/Phy (<3) in most cases indicate at least partial petrogenic contamination is likely in the study area. Therefore, samples collected from TJR runoff, microlayer, sediments, and sediment traps may contain relatively low levels of petrogenic hydrocarbons, in addition to those derived from the biogenic sources as previously discussed.

AH Inputs from Various Point Sources to the San Diego Coastal Marine Environment

The PLWTP and TJR constitute two major point sources of organic pollutants introduced into the coastal marine environment off San Diego. From the average daily flow of 6.5 ′ 108 L (City of San Diego 1994) for the PLWTP effluent discharge and the long-term annual mean flow of 43 ´ 106 m3 from 1955 to 1988 for the TJR runoff (SCCWRP 1992), the estimated annual mass emission inputs of AHs from PLWTP and TJR were 3,860 kg/yr and 101 kg/yr, respectively, in 1994. The annual mass emission of total AHs from the PLWTP outfall was approximately ten times higher than that of total PAHs estimated in *Compositional Indices of Polycyclic Aromatic Hydrocarbon Sources off San Diego, California* in this annual report. For the TJR, however, the ratio of annual mass emissions of AHs/PAHs was nearly 40. The substantial difference in the annual mass emission ratios of AHs/PAHs in these two point sources may be attributed to a relatively high level of biogenic contributions from terrestrial sources in the TJR runoff. This is supported by the predominance of the odd n-alkanes in the C_{25}-C_{33} range (Figure 2d). On the other hand, the organic contaminants in the PLWTP effluents were mainly originated from petrogenic sources.

The estimated mass emission of AHs from the PLWTP is much lower than those estimated for the effluents from other treatment plants. For instance, Barrick (1982) reported an annual mass emission of 30.6 mt/yr in 1978-79 for resolved AHs in the effluent from the Municipality of Metropolitan Seattle (METRO) sewage-treatment facility at Westpoint, Washington. The average daily flow volume (458 million L) of effluent discharged by the METRO facility in 1978-79 was nearly three times as that reported by the PLWTP in 1994. However, the annual mass emission of AH inputs from the METRO plant to the Central Puget Sound was nearly eight times the corresponding input from the PLWTP to the Southern California Bight. Improving processing technologies, including advanced primary treatment, adopted at PLWTP apparently played an important role in removing most of the AH contaminants from the effluents. In another study, Eganhouse and Kaplan (1982) reported AH mass emission rates in the range of 1,100 to 4,500 mt/yr obtained in 1979 from various major municipal wastewater dischargers in Southern California. In particular, the AH mass emission of 1,110 mt/yr was estimated for the effluents discharged from PLWTP in 1979 (Eganhouse and Kaplan 1982). This level of mass emission is noticeably higher than the amount estimated in our current study, despite the lower total effluent flow in 1979 (484 million L/day) relative to 1994 (650 million L/day). This further confirms that improved sewage treatment and source control are lowering the inputs of organic contaminants into the Southern California marine ecosystem.

The annual mass input of AHs for the TJR runoff was estimated to be 101 kg/yr in 1994. This figure was comparable to the total mass emission of 130 kg/yr reported by Mackenzie and Hunter (1979) for total petroleum hydrocarbons drained to the Delaware River during three storm events in 1975. These values are significantly lower than that (2,401 mt/yr) from the Los Angeles River as estimated by Eganhouse and Kaplan (1981). The estimation by Eganhouse and Kaplan (1981), however, was based on the results obtained during storm events in November 1978 that efficiently removed petroleum products on pavements.

Fate of Petrogenic and Biogenic Aliphatic Hydrocarbons

The results in the present study indicate that the molecular compositions of AHs in the coastal marine environment are significantly different from those of wastewater effluent and riverine runoff. In addition to several possible sources of inputs as previously discussed, these differences may also result from geophysical, geochemical, and biological processes that take place in the marine waters.

Upon entering the marine environment, AHs rapidly undergo various redistributions into four different areas: atmosphere, sea surface, upper water column, and bottom sediments (Kennish 1992). Depending on the corresponding partition coefficients, each constituent may exist in each medium at different concentrations. Hydrocarbons with low to medium molecular weights are more volatile and have a higher tendency to evaporate into the atmosphere. Significantly lower concentrations of C_{10} to C24 in the microlayer samples as compared to those in the PLWTP effluent and riverine runoff samples (Figure 2 and Figure 3) may thus be partially attributed to evaporation. In fact, evaporation losses accounted for the largest initial change in composition of oil spilled at sea (Kennish 1992).

Despite their hydrophobic nature, a small fraction of petroleum pollutants still dissolves in the water column. Similar to the evaporation rate, the solubility is inversely related to the molecular weights of the AHs (Kennish 1992). In addition, the degree of dissolution of each AH component also depends on the environmental conditions such as sea turbulence, wind, wave action, temperature, etc. In any event, dissolution is the primary step that leads to degradation of AHs by either abiotic or biotic processes. It has been reported that microbial degradation by marine bacteria plays a key role in the destruction of petroleum hydrocarbons (Kennish 1992, and references therein). The relative rates of microbial degradation, in general, are in the order of n-alkanes > branched alkanes > cyclic alkanes > aromatics (Wakeham and Farrington 1980). However, hydrocarbons of relatively long chain lengths, due to their strong hydrophobicity, tend to adsorb to particulate materials such as clay, sand, organic material, etc. These suspended particulates may undergo several cycles of resuspension and redeposition before finally being incorporated into "permanent" sediments (SCCWRP 1986). Most of the samples collected by the sediment traps contained significantly lower concentrations of the low molecular weight n-alkanes (25) (Figure 5), suggesting a significant loss of these hydrocarbons due to either evaporation, and/or degradation. This is further supported by the high concentrations of pristane in the samples collected at stations A-17 (5 m) and R-61 (1 and 5 m). The presence of relatively high concentrations of pristane as compared to phytane has often been taken as an indication for biological input resulting from degradation of ingested phytol by zooplankton as previously noted (Blumer *et al.* 1964). At both A-17 and R-61, the concentrations of total AHs in January 1994 were comparable at different depths (1 and 5 m). In June, however, the concentration of total AHs was significantly higher at 5 m than that at 1 m at R-61 (the 1-m traps at A-17 were lost in June). Interestingly, the concentration of total AHs at 1-m traps of R-61 was comparable to those at 1-m and 5-m traps of both A-17 and R-61 in January. Since aquatic organisms were more active during the warmer months (Serrazanetti *et al.* 1994), the seasonal variation in the total AHs may be attributed to the change in the hydrocarbon contributions derived from microbial production. For PAHs, on the other hand, their total concentration at A-17 decreased as the distance from the sea floor increased from 1 to 5 m (Compositional Indices of Polycyclic Aromatic Hydrocarbon Sources off San Diego, California in this annual report). This reverse trend may be a result of different bioconversion processes taking place in different marine organisms in addition to other effects induced by many abiotic factors. As discussed in the preceding article, PAHs in the study area were mainly derived from sewage and industrial effluents, combustion of fossil fuel, petroleum spills, etc. The change in the PAH concentrations within the aquatic environment was thus more likely due to their biological degradation or current circulation rather than due to additional biogenic input from marine organisms.

Acting as the ultimate repositories, sediments incorporate organic materials whose molecular compositions have been modified by various processes. During their residence in the sediments, organic contaminants continue to undergo further alterations. Benthic organisms can effectively alter the compositions of the organic contaminants via their active mixing of the deposited contaminants with the above resuspended particles and their ingestion and metabolism of hydrocarbons (Wakeham and Farrington 1980, and references therein). In addition, many animals and micro-organisms living in the sediments also produce biogenic AHs that are eventually accumulated in the sediments (Clark and Blumer 1967). The overall concentrations of AHs in the sediments were much lower than those found in the sediment trap particulates (Table 1), possibly reflecting the importance of degradation and/or resuspension of components derived from biological activities.

CONCLUSIONS

The results obtained from the measurements of AHs in the PLWTP effluent, TJR runoff, and microlayer, sediment traps, and sediments at various locations in the coastal marine environment off San Diego suggest that these contaminants were largely derived from both biogenic and anthropogenic petroleum sources. Several mechanisms, including diffusion, solubilization, evaporation, and microbial degradation are believed to be responsible for the difference in the concentrations and compositions of AHs in different sample media. The relative importance of each mechanism, however, can not be readily discerned from the available data. Nevertheless, it is evident that petroleum-derived contaminants still persist in the coastal environment. In addition to the contributions by the effluent and surface runoff, hydrocarbon contaminants may also be airborne from terrestrial sources to the coastal waters. Thus, similar studies focusing on nonpoint source inputs in the area should be conducted before any attempt can be made to elucidate the relative importance of each pathway by which organic pollutants are introduced to this coastal environment.

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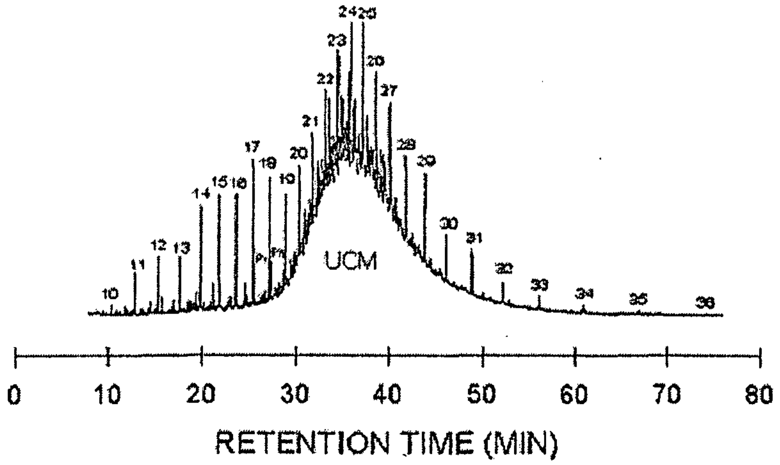
FIGURES

FIGURE 1.

A typical gas chromatogram of the aliphatic hydrocarbon fraction in Point Loma Wastewater Treatment Plant effluent particulates collected in June 1994. The numbers close to the resolved peaks indicate the carbon numbers in n-alkanes. Pr = pristane; Ph = phytane; and UCM = unresolved complex mixture.



Return to Results

FIGURE 2.

Compositional patterns of aliphatic hydrocarbon compounds in Point Loma Wastewater Treatment Plant effluent and Tijuana River runoff samples collected in January (¡) and June (u)1994. Concentrations are expressed in ng/g dry weight for particulate samples and in ng/L for filtrate samples. Pr = pristane and Ph = phytane.

| Return to TJR Runoff | Return to Microlayer |

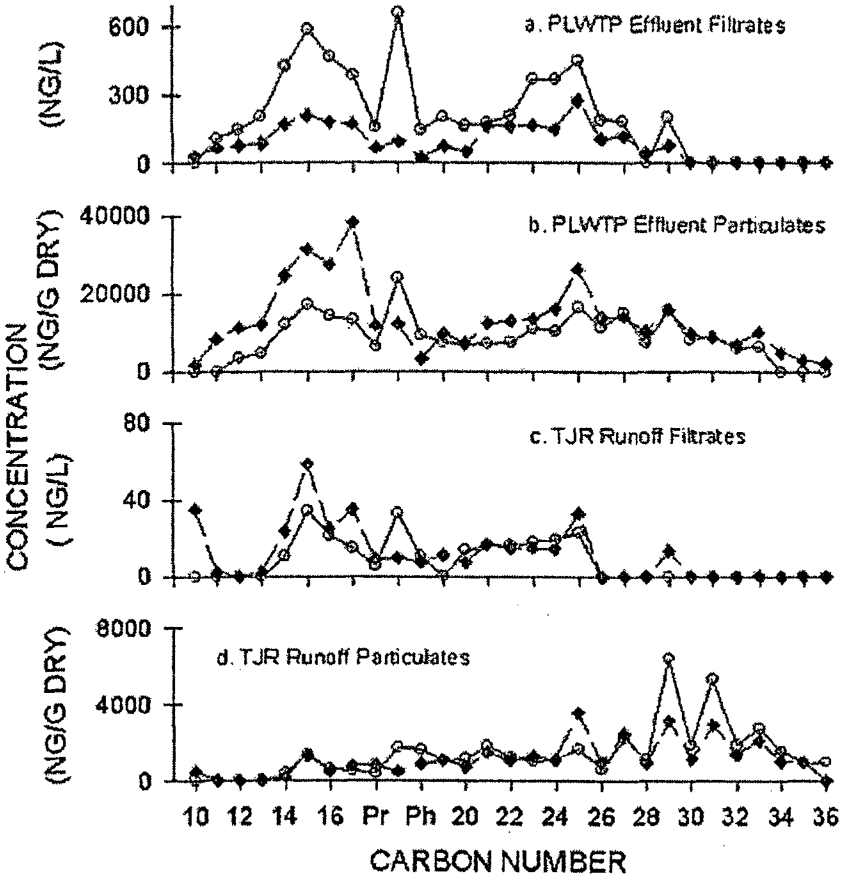
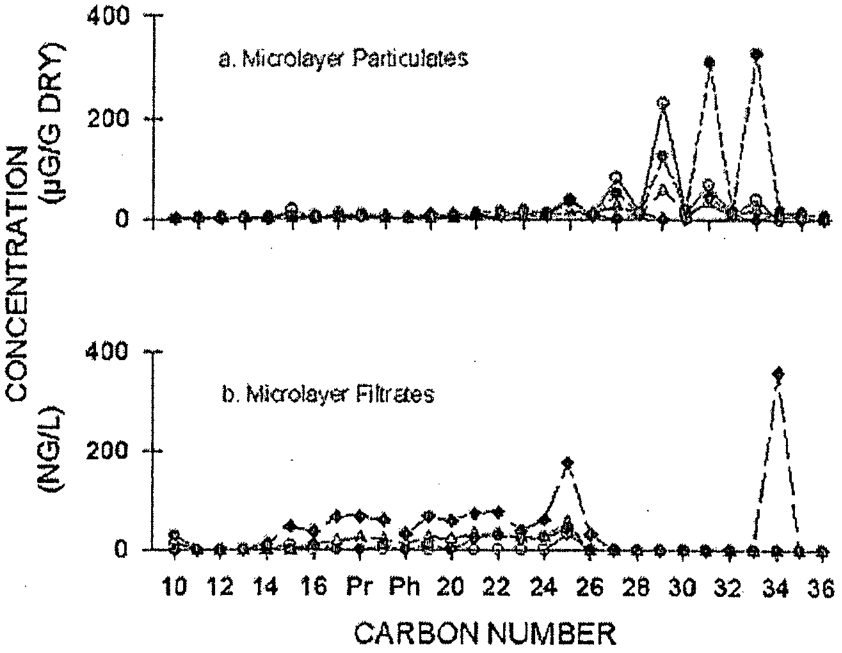


FIGURE 3.
Compositional patterns of aliphatic hydrocarbon compounds in microlayer samples collected at stations A-17, R-61, MTJR, and SDB off San Diego, California, in June 1994. ¡: A-17; u: R-61; D: MTJR; l: SDB. Concentrations are expressed in ng/g dry weight for particulate samples and in ng/L for filtrate samples. Pr = pristane and Ph = phytane.

Return to Microlayer |



P> **FIGURE 4.**
Compositional patterns of aliphatic hydrocarbons compounds in sediments collected at stations A-17, R-61, MTJR, and SDB off San Diego, California, in January (¡) and June (u)1994. Concentrations are expressed in ng/g dry weight. Pr = pristane and Ph = phytane.

| Return to Sediment Trap Particulates | | Return to Sediments |

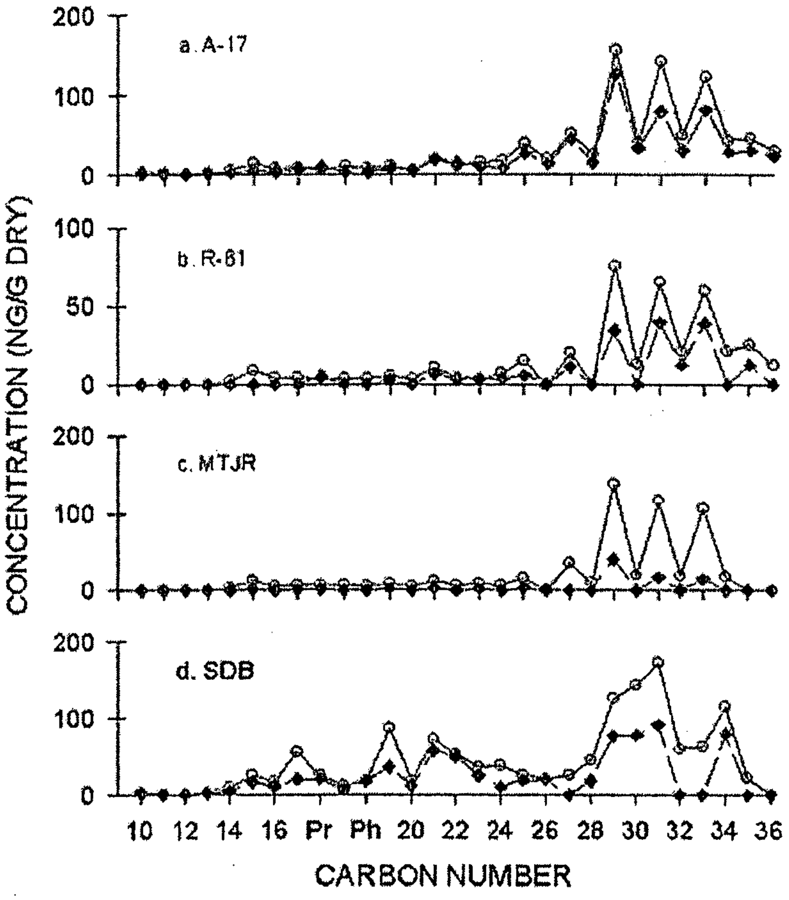
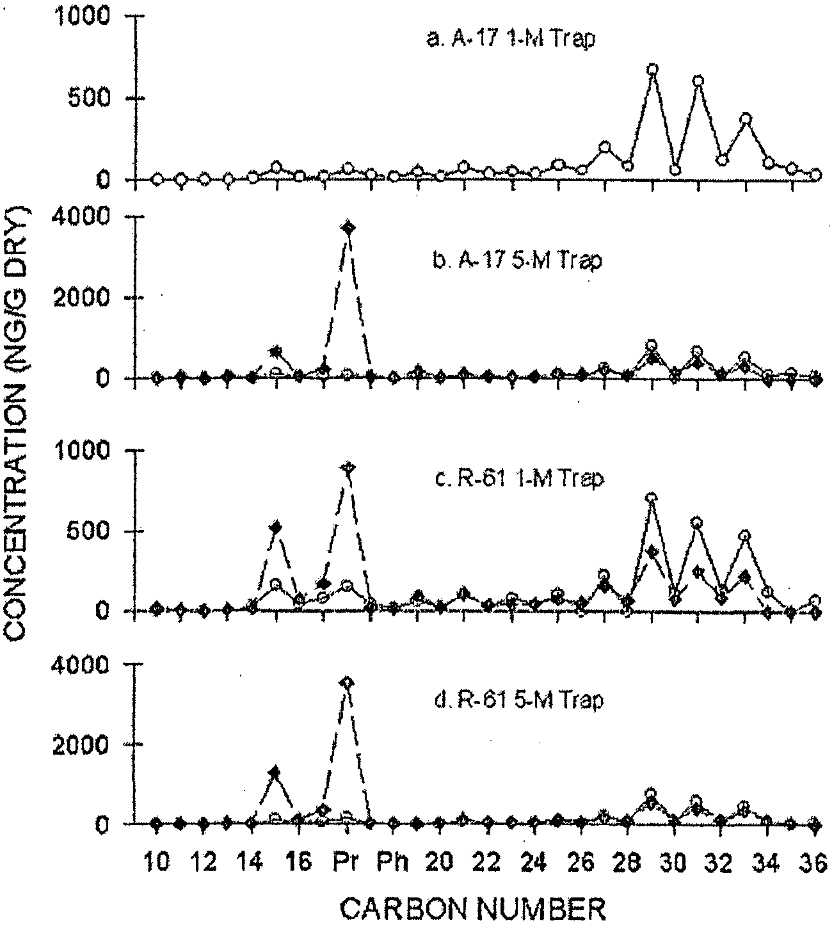


FIGURE 5.
Compositional patterns of aliphatic hydrocarbons compounds in sediment trap particulates collected at stations A-17 and R-61 off San Diego, California, in January (¡) and June (u)1994. Concentrations are expressed in ng/g dry weight. Pr = pristane and Ph = phytane.

| Return to Sediment Trap Particulates |



TABLES

TABLE 1.
Concentrations and compositional indicesa of aliphatic hydrocarbon (AH) compounds measured in samples collected off San Diego, California, in 1994.

| Return to Results
| Return to TJR Runoff | Return to Microlayer | Return to Sediments | Return to Sediment Trap Particulates | Return to Discussion |

	Total AHs (dry wt based)b		Total AHs (TOC based)c		MH		LMW/HMW		n-C_{16} Ratio		CPI		C_{17}/Pri		C_{18}/Phy		Pri/Ph	
Sample Type	Jan-94	Jun-94	Jan-94	Jun-94	Jan-94	Jun-94	Jan-94	Jun-94	Jan-94	Jun-94	Jan-94	Jun-94	Jan-94	Jun-94	Jan-94	Jun-94	Jan-94	Ju 9
	PLWTP Effluent																	
Filtrates	5.82	2.56	NA	NA	C_{18}	C_{25}	1.6	1	12	14	4.1	2.1	2.4	2.7	4.5	4	1.1	2.
Particulates	247	377	717	1060			0.8	1	16	13	1.8	1.4	2.1	3.2	2.6	4	0.68	3.

					C_{18}	C_{17}												
		-13.8	-10.4															
	Tijuana River Runoff																	
Filtrates	0.237	0.337	NA	NA	C_{34}	C_{15}	1.7	1.9	10	13	NA	NA	2.7	3.7	3.1	1.2	0.52	1.
Particulates	41.4	32.9	406	404	C_{29}	C_{25}	0.21	0.22	64	65	3.7	2.8	1.2	0.99	1.1	0.54	0.26	0.
		-3.64	- 0.494															
	Microlayer																	
A-17 Filtrates	NA	0.054	NA	NA	NA	C_{29}	NA	0.69	NA	NA	NA	NA	NA	NA	NA	NA	NA	N.
A-17 Particulates	NA	553	NA	4290	NA	C_{29}	NA	0.065	NA	NA	NA	14	NA	3.6	NA	1.2	NA	2.
R-61 Filtrates	NA	1.28	NA	NA	NA	C_{34}	NA	0.43	NA	31	NA	0	NA	0.99	NA	1.9	NA	2.
R-61 Particulates	NA	195	NA	943	NA	C_{31}	NA	0.21	NA	77	NA	0	NA	0.99	NA	1.4	NA	1.
MTJR Filtrates	NA	0.328	NA	NA	NA	C_{29}	NA	0.68	NA	24	NA	NA	NA	0.75	NA	2.0	NA	2.
MTJR Particulates	NA	211	NA	2130	NA	C_{29}	NA	0.025	NA	490	NA	4.1	NA	0.55	NA	1.3	NA	2.
SDB Filtrates	NA	0.206	NA	NA	NA	C_{29}	NA	0.42	NA	21	NA	NA	NA	NA	NA	NA	NA	N.
SDB Particulates	NA	1020	NA	11900	NA	C_{33}	NA	0.034	NA	250	NA	8.5	NA	0.84	NA	0.99	NA	2.
	Sediments																	
A-17	0.928	0.666	172	130	C_{29}	C_{29}	0.083	0.084	120	150	3.8	4.2	1.1	0.78	1.6	0.95	1.2	2.
R-61	0.391	0.179	46.5	32.4	C_{29}	C_{31}	0.086	0.014	91	NA	14	NA	1.2	0	0.89	NA	1.1	N
MTJR	0.578	0.091	155	75.6	C_{29}	C_{29}	0.1	0.064	110	NA	8.5	NA	1.2	0.61	1.3	NA	1.1	[illegible]
SDB	1.29	0.68	157	82	C_{31}	C_{31}	0.22	0.22	75	56	1.2	1.1	2.1	0.97	0.55	0.39	1.4	1.
	Sediment Trap Particulates																	
A-17 (1 m)	3.01	**[d]	159	**	C_{29}	**	0.081	**	200	**	6	**	0.29	**	1.4	**	2.9	*
A-17 (5 m)	3.57	7.46	160	254	C_{29}	Pri	0.082	0.59	150	55	8.7	3.2	0.24	0.063	1.5	1.8	4.7	2
R-61 (1 m)	3.39	3.46	138	135	C_{29}	Pri	0.16	0.58	71	35	17	3.9	0.54	0.19	2.3	1.5	7.7	8.
R-61 (5 m)	3.4	8.03	124	249	C_{29}	Pri	0.11	0.81	87	34	6	4.1	0.51	0.1	1.6	2.0	12	1

a See text for the definitions of the compositional indices. **b** In mg/g dry weight for solid samples and mg/L for aqueous samples; the numbers in parentheses are concentrations based on the aqueous volumes, in mg/L. **c** In mg/g TOC for solid samples; TOC was not measured for aqueous samples. NA=not analyzed (see text). **d** A-17 1-m traps were not recovered in June 1994.

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Petrotech Bioremediation Demonstration

(Cold Climate Application)

Introduction:

Since September of 1998, the client operated an oily waste bioremediation soil treatment facility at its fuel storage facility in order to remove petroleum constituents to an acceptable level, as defined by permit. The demonstration began in late September of 1998 and was discontinued September 20, 1999 due to a need to utilize the bioremediation bed area for a planned contaminated soil removal. Winter cold weather essentially inhibited any remedial activity beginning November 1998 through March 1999. The initial operation included blending of heavily weathered crude oil sludge with soil, Petrotech surfactant solution and appropriate nutrients to support microbial activity. Placement of windrows, periodic turning of the windrows, maintenance of the nutrient concentrations and Petrotech additions continued during the warmer months, based on relevant analytical information provided from monthly sampling and analysis.

Site Reports:

The windrow heights were maintained at approximately 24- 36 inches over the bed floor during the operation. Other indigenous contaminated soils (mostly an extremely fine glacial till with plant matter) were blended in with the sludge at the beginning of treatment and incorporated into the windrows. The windrows were turned and agitated by using a mechanical rake on a hydraulic track excavator.

Composite sampling was conducted monthly to allow for monitoring of progress and nutrient requirements

Laboratory Findings

Polyaromatic Hydrocarbons (PAHs):

Fifteen Polyaromatic Hydrocarbon (PAH) compounds are specifically regulated. The regulatory limit was set by permit at 100.0 mg/kg total PAH and is defined as the sum of the concentrations of those fifteen compounds. The total PAH value on the blended sludge at the beginning of treatment was 547 mg/l. Laboratory test results demonstrated a steady decrease in the regulated constituents over the treatment period. The last two samplings (June 29,1999 and July 23, 1999) reported PAH concentrations at 88 mg/kg and 83 mg/kg respectively. These results indicate that the material consistently meets the applicable Total PAH limits.

A total PAH reduction of 85% was obtained within 9-10 months of operation.

2) The BTEX constituents and PAHs were degraded to the cleanup criteria within 9 months of operation using Petrotech.

Journal of Soil Contamination, 2(1): (1993)

Review of Chemical, Physical, and Toxicologic Properties of Components of Total Petroleum Hydrocarbons

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ABSTRACT: Risk is a function of exposure and hazard, and both aspects must be incorporated into sound risk assessment efforts. However, risk assessment for sites contaminated with petroleum products is complicated by a general lack of information relevant to exposure to and toxicity of petroleum mixtures (especially total petroleum hydrocarbons, or TPH). Specifically, there is often inadequate information about the components of the TPH present at the site and the physical and chemical properties and toxicities of these components. Such information is crucial to developing a strong conceptual model of exposure to and risk from petroleum hydrocarbons at contaminated sites. This article presents information that can be incorporated into risk assessments for sites contaminated with petroleum hydrocarbons.

KEY WORDS: petroleum contamination, total petroleum hydrocarbons, risk assessment, toxicity, physical/chemical properties.

I. BACKGROUND

Environmental contamination by petroleum products is a significant concern throughout the U.S. It is estimated that there are over 2 million underground storage tanks subject to the federal underground storage tank regulations designed to minimize potential releases (Valentinetti, 1989). Not included in this figure are other sources of petroleum product contamination, such as heating oil tanks (which are not subject to the regulations), refineries, aboveground tanks, terminals, pipelines, or accidental spills from other sources. An understanding of the risks associated with releases from these sources is crucial to effective decision making about both prevention and remediation of releases. However, as lamented by Bauman of the American Petroleum Institute (1989), risk assessment efforts for petroleum hydrocarbons in environmental media are frustrated significantly by the complex nature of petroleum products, the lack of adequate knowledge about the movement of petroleum components in soil, and the lack of knowledge about the

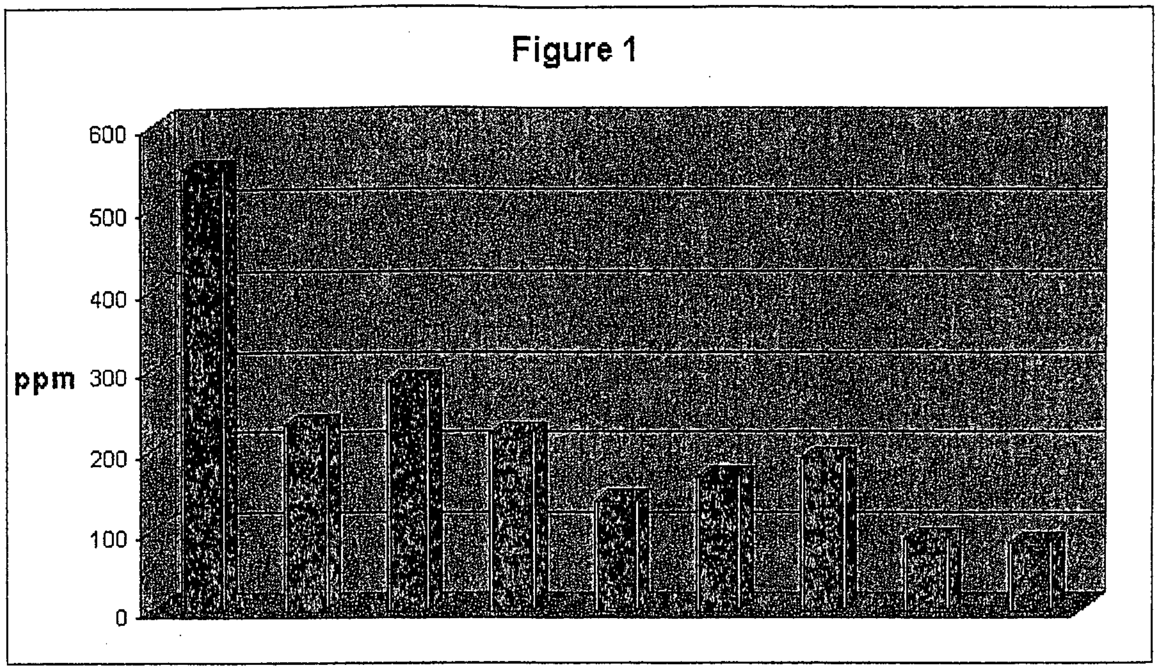


Figure 1

	09/25/98 Sludge Blended	10/17/98 Composite Window	11/13/98 Composite Window	12/11/98 Composite Window	03/29/99 Composite Window	05/6/99 Composite Window	06/1/99 Composite Window	06/29/99 S.G.Clean Window	07/23/99 S.G.Clean Window
Total PAH	546.79	231.07	284.79	220.19	137.11	166.74	189.88	88.43	83.36

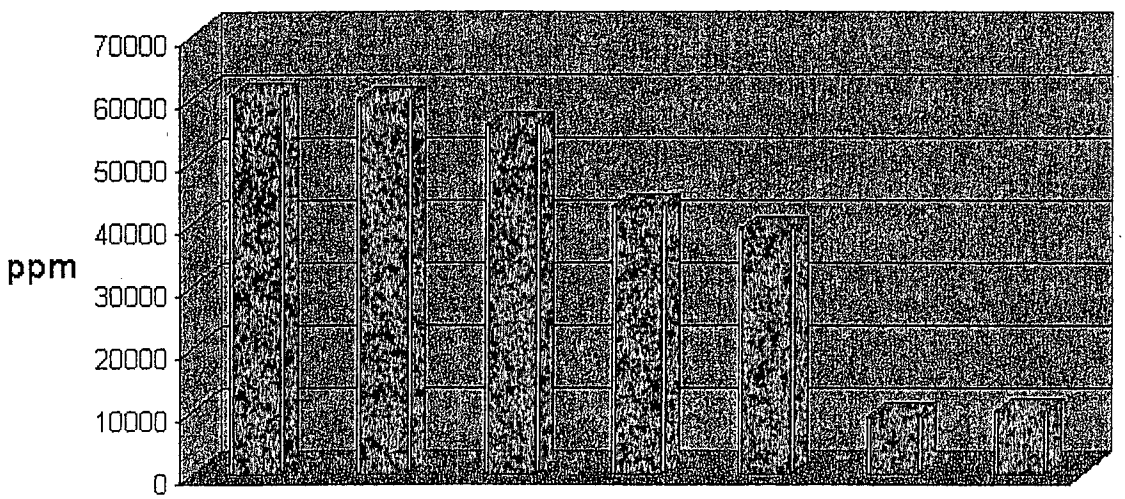
Constituents

Total Petroleum Hydrocarbon:

Total Petroleum Hydrocarbon (TPH) is regulated by permit. The permit limits are established at 2000 ppm for the use of the material as industrial fill. TPH is defined by permit as the sum of petrogenic hydrocarbons having six to thirty two carbon atoms (C6-C32). TPH is determined analytically by the sum of the aliphatic fraction and the aromatic fraction eluting between n-hexane and n-dotriacontane. Aliphatics are separated from the aromatics by eluting them off of an alumina column into their preferred solvent. The quantification is accomplished by Gas Chromatography with a Flame Ionization Detector (GC/FID) or a Mass Ion Detector (GC/MS). The GC/MS method is more selective, as compounds can be specifically identified and non-petrogenic hydrocarbons eliminated from the quantification; the GC/FID provides quantification of all the hydrocarbon (petrogenic and non-petrogenic) in a sample. The laboratory initially used the GC/FID method (generally the method of choice) to determine TPH and, because of the large amount of non-petrogenic hydrocarbon present due to degradation, was unable to accurately assess the mid and high range petroleum hydrocarbon quantity. Cleanup methods (Silica Gel Cleanup) were implemented in June 1999 by the laboratory and demonstrated removal of a large amount of interfering material. Specifically, the TPH before silica gel cleanup was reported at 65,306 mg/kg, after silica gel cleanup the sample exhibited only 35,798 mg/kg. It was suspected, however, that other interferents remained. Sample cleanup and GC/MS methodologies were instituted for the final two sampling events (EPA Methods 3650, 3611B and 8270B - modified as allowed by SW-846 for TPH Quantification). The Total Petroleum Hydrocarbon result using this method was 9160 mg/kg (for the sample collected July 23, 1999) and 10020 mg/kg (for the sample collected September 14, 1999). The laboratory reported a more efficient extraction on the most recent sample, this most likely accounts for the slight increase as reported.

A total TPH reduction of 78-82 % was obtained during the demonstration.

Figure 2



	09/17/98 Sludge Window	11/13/98 Composite Window	05/6/99 Composite Window	06/29/99 S.G.Clean Window	07/23/99 S.G.Clean Window	07/23/99 GC/MS Window	9/14/99 GC/MS Window
Total TPH	60330	59750	55821	42580	39107	9160	10024

Constituents

Aliphatics:

Aliphatic Fraction - The aliphatics fraction proved to be the most difficult to quantify. The C6-C10 fraction was reduced to below detection limits as of the July 23, 1999 sampling. Results of the split sampling analyzed by GC/MS indicate the Total Petroleum Aliphatic content was 3980 mg/kg or 43% of the Total Petroleum Hydrocarbon result (for the July 23, 1999 sample) and 3480 mg/kg or 35% of the Total Petroleum Hydrocarbon result (for September 14, 1999 sample). These results suggest that the aliphatic fraction of this material preferentially degrades. The two largest components of the aliphatic toxicity of these components. This article provides information that can be used to develop a better understanding of the petroleum components present at sites, their movement in the environment, and their toxicity.

Once a release has occurred, environmental media at petroleum-contaminated sites are typically sampled and analyzed for a handful of specific compounds (such as benzene, toluene, ethylbenzene, xylenes (BTEX), and lead), and for total petroleum hydrocarbons (TPH). The BTEX components of petroleum products can be identified and quantified, and their toxicity and mobility in the environment are relatively well understood. However, although chemical analysis for TPH is relatively simple and inexpensive, this measure of petroleum components presents challenges to risk assessors. For instance, the label "total" implies that analysis for TPH includes all petroleum hydrocarbons, which is far from true. Although several methods are available, each actually measures only a specific range of the hydrocarbon components (Bauman, 1991). Because petroleum product composition varies among sources and over time (as a result of weathering and environmental fate and transport processes), the same concentration of TPH at two different sites may represent very different mixtures and, therefore, very different risks to human health and the environment (Bauman, 1991; Millner *et al.*, 1992).

Although the analytical approaches for TPH in the environment may satisfy the informational needs of regulatory agencies and engineers designing remediation activities, the level of detail (or lack thereof) presents significant challenges to risk assessors who must evaluate the movement of petroleum components in the environment, consider the inherent hazards associated with these chemicals (toxicity), and estimate the risks these releases pose to human and ecological receptors. For instance, the polycyclic aromatic hydrocarbon content of diesel varies significantly across diesel products and could significantly affect the toxicity of the TPH mixtures present in the environment (Block *et al.*, 1991). Risk assessors typically select surrogate compounds (or combinations of compounds) to represent TPH so that movement in the environment and toxicity can be evaluated manageably.

Three types of information contribute to selection of surrogate compounds for TPH: (1) the composition of TPH at the site, (2) information about the chemical and physical properties of the TPH components, and (3) information quantifying the inherent toxicity of the components. This paper presents a compilation of information about the composition of TPH from various sources, available chemical and physical information about these components, and available toxicity information about them. This information can be applied to select surrogate compounds for TPH.

II. COMPONENTS OF TPH

Information about the composition of TPH from a variety of sources is summarized in Tables 1 and 2. The considered petroleum product sources include gasoline,

TABLE 1
Composition of Gasoline-Based TPH

Constituents	Gasoline weight (%)	Regular unleaded gasoline volume (%)	Premium unleaded gasoline volume (%)	Leaded gasoline volume (%)	Water-soluble-phase regular leaded gasoline (ppb)	Water-soluble-phase regular unleaded gasoline (ppb)	Water-soluble-phase super unleaded gasoline (ppb)
Alcohols							
2-Butoxyethanol							16,800
Ethyl alcohol		<5	<5				
Methyl alcohol		0.2	0.2				
t-Butyl alcohol					22,300	15,900	933,000
Cycloalkanes							
Cyclopentane	0.19–0.58						
1-*trans*-3-Dimethylcyclohexane	0.05–0.12						
1-*cis*-2-Dimethylcyclopentane	0.07–0.13						
1-*trans*-2-Dimethylcyclopentane	0.06–0.20						
Ethylcyclohexane	0.17–0.42						
Ethylcyclopentane	0.14–0.21						
1-Methyl-*cis*-2-ethylcyclopentane	0.06–0.11						
1-Methyl-*trans*-3-Ethylcyclopentane	0.06–0.12						
Isopropylcyclopentane	0.01–0.02						
n-Propylcyclopentane	0.01–0.06						
1,1,2-Trimethylcyclopentane	0.06–0.11						
1-*trans*-2-*cis*-3-Trimethylcyclopentane	0.01–0.25						
1-*trans*-2-*cis*-4-Trimethylcyclopentane	0.03–0.15						
Cycloalkenes							
Cyclohexene	0.03						
Cyclopentene	0.12–0.18				5190		
3-Methylcyclopentene	0.03–0.08						
Chlorinated aliphatics							
Dibromoethane				190 mg/l	576		
1,2-Dichloroethane	150–300				1330		
1,1-Dichloroethane				210 mg/l			
Ethylene dibromide	0.7–177.2 mg/kg						

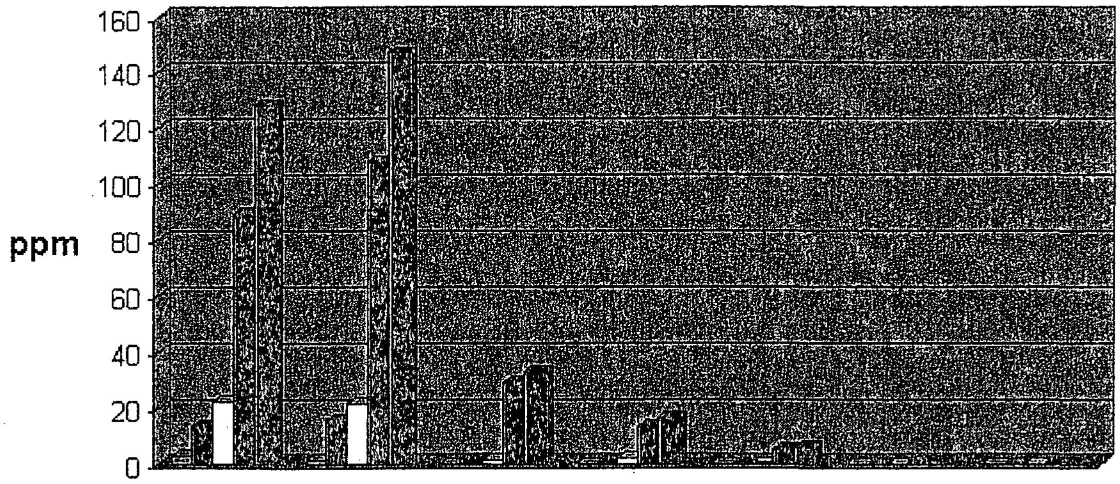
fraction are the two isoprenoids, pristane and phytane. Isoprenoids tend to degrade after the straight chain hydrocarbons. As a whole, however, the predominant aliphatic components still present at the conclusion of operation are straight chain hydrocarbons.

Aromatics:

BTEX constituents and Benzene are specifically regulated by permit. The permit limits were established at 200 ppm and 2 ppm respectively. Only one sample (December 11, 1998) taken during the operation exceeded the BTEX limit. The results from all samples analyzed in CY 1999 demonstrated a consistent decline in BTEX constituents; the sampling (July 23,1999) demonstrated that *all* BTEX constituents were non-detectable. Benzene was below detection limits for the final three BTEX sampling events (June 1, June 29, and July 23).

BTEX constituents and Benzene were degraded to below mandated cleanup criteria.

Figure 3



	10/17/98	11/13/98	3/29/99	5/6/99	6/1/99	6/29/99	7/23/99	
	Composite	Composite	Composite	Composite	Composite	S.G. Clean	S.G. Clean	
	Window	Window	Window	Window	Window	Window	Window	
Benzene	3.04	1.50	0	0	0.12	0.00	0.00	
Toluene	13.50	15.90	2.10	0.80	0.23	0.00	0.00	
Ethylbenzene	22.30	21.50	1.60	2.20	0.46	0.00	0.00	
Total Xylene	89.20	108.00	29.10	13.60	5.29	1.29	0.00	

Total BTEX	128.04	146.90	32.80	16.60	6.10	1.29	0.00	

Constituents

Aiomatic Fraction:

Aromatic Fraction -The C6-C10 aromatics were reduced to below detection limits. All aromatics at the conclusion were C11-C32 range compounds. Results of the final sampling (September 14, 1999) indicate the Total Petroleum Aromatic Hydrocarbon content is 6440 mg/kg or 64% of the Total Petroleum Hydrocarbon result. The aromatic fraction consisted primarily of alkyl substituted PAHs (e.g. methyl substituted naphthylenes, methyl substituted chrysenes). These results are in agreement with the laboratories earlier report of 5769 mg/kg on a June 1, 1999 sample.

Isoprenoids :

Pristane and phytane are the two predominant isoprenoids found in petroleum products. They are, in essence, "chemical fossils" from the hydrolysis of chlorophyll and tend to degrade after the straight chain aliphatics. They can be quantified in the aliphatic fraction by GC/FID or GC/MS. The split sample (July 23, 1999) was analyzed by GC/MS for aliphatic compounds. Pristane and phytane were the predominant compounds present. This indicates that most of the other aliphatics were substantially degraded.

Microbiological Assays:

Microscopic examination of a split sample (June 1,1999) revealed the presence of both bacterial and, apparently, several fungal species. The received sample was reported at a pH of 4.9. There was a dominance of filamentous and fungal forms in the sample as received. Lees and Senior (1980's) have previously reported that isoprenoids (pristane) and hexadecane (C18 straight chain) are metabolized by different species of organisms; isoprenoids by bacteria and hexadecane by filamentous fungi. The degrading population at a Shell bioremediation facility similar to Statia's existed together in a honeycomb-like matrix and was held together by a network of extracellular fibers. Material pH greater than seven resulted in bacterial dominance, pH less than seven resulted in fungal dominance. Our observations are consistent with this research and suggest that pH shifting has influenced degradation of the specific fractions that remained. Too low or too high a pH, however, would have encumbered any beneficial microbial population.

Conclusions:

1) A 78-82% reduction in TPH was achieved during the elapsed one year of operation using Petrotech. Climate conditions at this site allow for optimal (temperate) conditions only 5 to 7 months of the year.

TABLE 1 (continued)
Composition of Gasoline-Based TPH

Constituents	Gasoline weight (%)	Regular unleaded gasoline volume (%)	Premium unleaded gasoline volume (%)	Leaded gasoline volume (%)	Water-soluble-phase regular leaded gasoline (ppb)	Water-soluble-phase regular unleaded gasoline (ppb)	Water-soluble-phase super unleaded gasoline (ppb)
Ethyl alkanes/alkenes							
5-Ethylheptane	0.02–0.16						
3-Ethylhexane	0.01						
3-Ethyl-2-pentene	0.03–0.04						
Ether							
Methyl-*t*-butyl ether		<12	<12		43,700	35,100	966,000
Methyl alkanes							
2,2-Dimethylbutane	0.17–0.84						
2,3-Dimethylbutane	0.59–1.55						
2,4-Dimethyl-3-ethylpentane	0.03–0.07						
2,2-Dimethylheptane	0.01–0.08						
2,3-Dimethylheptane	0.13–0.51						
2,6-Dimethylheptane	0.07–0.23						
3,3-Dimethylheptane	0.01–0.08						
3,4-Dimethylheptane	0.07–0.33						
2,4-Dimethylhexane	0.34–0.82						
2,5-Dimethylhexane	0.24–0.52						
3,4-Dimethylhexane	0.16–0.37						
2,6-Dimethyloctane	0.06–0.12						
2,3-Dimethylpentane	0.32–4.17						
2,4-Dimethylpentane	0.23–1.71						
3,3-Dimethylpentane	0.02–0.03						
2-Methyl-3-ethylhexane	0.04–0.13				9,930		
2-Methylbutane							
2-Methylheptane	0.48–1.05						
3-Methylheptane	0.63–1.54						
4-Methylheptane	0.22–0.52						
2-Methylhexane	0.36–1.48						
3-Methylhexane	0.3–1.77						

TABLE 1 (continued)

Composition of Gasoline-Based TPH

Constituents	Gasoline weight (%)	Regular unleaded gasoline volume (%)	Premium unleaded gasoline volume (%)	Leaded gasoline volume (%)	Water-soluble-phase regular leaded gasoline (ppb)	Water-soluble-phase regular unleaded gasoline (ppb)	Water-soluble-phase super unleaded gasoline (ppb)
2-Methylnonane	0.06–0.41						
3-Methylnonane	0.06–0.32						
4-Methylnonane	0.04–0.26						
2-Methyloctane	0.14–0.62						
3-Methyloctane	0.34–0.85						
4-Methyloctane	0.11–0.55						
2-Methylpentane	2.91–3.85						
3-Methylpentane	2.4						
2,2,3-Trimethylbutane	0.01–0.04						
2,2,4-Trimethylheptane	0.12–1.7						
3,3,5-Trimethylheptane	0.02–0.06						
2,2,4-Trimethylhexane	0.11–0.18						
2,2,5-Trimethylhexane	0.17–5.89						
2,3,3-Trimethylhexane	0.05–0.12						
2,3,5-Trimethylhexane	0.05–1.09						
2,4,4-Trimethylhexane	0.02–0.16						
2,2,3-Trimethylpentane	0.09–0.23						
2,2,4-Trimethylpentane	0.32–4.58						
2,3,3-Trimethylpentane	0.05–2.28						
2,3,4-Trimethylpentane	0.11–2.8						
Methyl alkenes							
2,3-Dimethyl-1-butene	0.08–0.1						
2,3-Dimethyl-1-pentene	0.01–0.02						
2,4-Dimethyl-1-pentene	0.02–0.03						
4,4-Dimethyl-1-pentene	0.6 (vol.)						
4,4-Dimethyl-*cis*-2-pentene	0.02						
2-Methyl-1-butene	0.22–0.66						
2-Methyl-2-butene	0.96–1.28						
2-Methyl-1-pentene	0.2–0.22						
2-Methyl-2-pentene	0.27–0.32						
3-Methyl-1-butene	0.08–0.12	0.06–0.08	0.06–0.08	0.06–0.08			
3-Methyl-*cis*-2-pentene	0.35–0.45						
3-Methyl-*trans*-2-pentene	0.32–0.44						
4-Methyl-*cis*-2-pentene	0.04–0.05						
4-Methyl-*trans*-2-pentene	0.08–0.3						

TABLE 1 (continued)
Composition of Gasoline-Based TPH

Constituents	Gasoline weight (%)	Regular unleaded gasoline volume (%)	Premium unleaded gasoline volume (%)	Leaded gasoline volume (%)	Water-soluble-phase regular leaded gasoline (ppb)	Water-soluble-phase regular unleaded gasoline (ppb)	Water-soluble-phase super unleaded gasoline (ppb)
Monocyclic aromatic hydrocarbons							
Benzene	0.12-3.5	2-5	2-5	2-5	30,500	28,100	67,000
n-Butylbenzene	0.04-0.44	0.08	0.08	0.2-0.5			
sec-Butylbenzene	0.01-0.13						
t-Butylbenzene	0.12						
1,2-Diethylbenzene	0.57						
1,3-Diethylbenzene	0.05-0.38						
1,2-Dimethyl-3-ethylbenzene	0.02-0.19						
1,2-Dimethyl-4-ethylbenzene	0.5-0.73						
1,3-Dimethyl-2-ethylbenzene	0.21-0.59						
1,3-Dimethyl-4-ethylbenzene	0.03-0.44						
1,3-Dimethyl-5-ethylbenzene	0.11-0.42						
1,3-Dimethyl-5-t-butylbenzene	0.02-0.16						
1,4-Dimethyl-2-ethylbenzene	0.05-0.36						
Ethylbenzene	0.36–2.86	5	5	5	4,040	2,420	7,400
Isobutylbenzene	0.01–0.08						
Isopentylbenzene	0.07–0.17						
eip-Isopropylbenzene	<0.01–0.23						
1-Methyl-4-ethylbenzene	0.18–1						
1-Methyl-2-ethylbenzene	0.19–0.56						
1-Methyl-3-ethylbenzene	0.31–2.86						
1-Methyl-2-*n*-propylbenzene	0.01–0.17						
1-Methyl-3-*n*-propylbenzene	0.08–0.56						
1-Methyl-3-isopropylbenzene	0.01–0.12						
1-Methyl-3-*t*-butylbenzene	0.03–0.11						
1-Methyl-4-*t*-butylbenzene	0.04–0.13						
n-Pentylbenzene	0.01–0.14						
n-Propylbenzene	0.08–0.72	0.6	0.6				
1,2,3,4-Tetramethylbenzene	0.02–0.19						
1,2,3,5-Tetramethylbenzene	0.14–1.06						
1,2,4,5-Tetramethylbenzene	0.05–0.67						
Toluene	2.73–21.8	6–7	6–7	6–7	31,400	31,100	107,400
1,2,3-Trimethylbenzene	0.21–0.48	0.73	0.73	0.73			
1,2,4-Trimethylbenzene	0.66–3.3						
1,3,5-Trimethylbenzene	0.13–1.15	1.3	1.3	1.3			

TABLE 1 (continued)
Composition of Gasoline-Based TPH

Constituents	Gasoline weight (%)	Regular unleaded gasoline volume (%)	Premium unleaded gasoline volume (%)	Leaded gasoline volume (%)	Water-soluble-phase regular leaded gasoline (ppb)	Water-soluble-phase regular unleaded gasoline (ppb)	Water-soluble-phase super unleaded gasoline (ppb)
o-Xylene	0.68–2.86						
m-Xylene	1.77–3.87				13,900	10,900	11,500
o,p-Xylenes						4,840	5,660
p-Xylene	0.77–1.58						
Xylenes		6–7	6–7	6–7			
Polycyclic aromatic hydrocarbons							
Anthracene		1.55–1.84 mg/l	1.55–1.87 mg/l	1.55 mg/l			
Benzo*[a]*pyrene	0.19–2.8 mg/kg						
Benzo*[b]*fluoranthene		3.9 mg/l	3.9 mg/l	3.9 mg/l			
Benzo*[e]*pyrene		0.3 mg	0.3 mg	0.3 mg/l			
Fluoranthene		1.84 mg/l	1.84 mg/l	1.84 mg/l			
Naphthalene	0.09–0.49	0.2–0.5	0.2–0.5	0.08			
Simple alkanes							
n-Butane	3.93–4.7	4–5	4–5	4–5			
n-Decane	0.04–0.5						
n-Dodecane	0.04–0.09						
n-Heptane	0.31–1.96						
n-Hexane	0.24–3.5						
Isobutane	0.12–0.37	0.7–1	0.7–1	0.1			
Isopentane	6.07–10.17	9–11	9–11	9–11			
Neopentane	0.02–0.05						
n-Nonane	0.07–0.83						
n-Octane	0.36–1.43						
n-Pentane	5.73–10.92	2.6–2.7	2.6–2.7	2.6–2.7			
Propane	0.01–0.14	0.07–0.08	0.07–0.08	0.07–0.08			
n-Undecane	0.05–0.22						

TABLE 1 (continued)
Composition of Gasoline-Based TPH

Constituents	Gasoline weight (%)	Regular unleaded gasoline volume (%)	Premium unleaded gasoline volume (%)	Leaded gasoline volume (%)	Water-soluble-phase regular leaded gasoline (ppb)	Water-soluble-phase regular unleaded gasoline (ppb)	Water-soluble-phase super unleaded gasoline (ppb)
Simple alkenes							
2-Butene		0.16–0.17	0.16–0.17	0.16–0.17	5,870	4,740	8,790
cis-2-Butene	0.13–0.17						
trans-2-Butene	0.16–0.2						
cis-3-Heptene	0.14–0.17						
trans-3-Heptene	0.06–0.1						
cis-2-Hexene	0.15–0.24						
trans-2-Hexene	0.18–0.36						
cis-3-Hexene	0.11–0.13						
trans-3-Hexene	0.12–0.15						
1-Pentene	0.33–0.45						
2-Pentene						22,500	
cis-2-Pentene	0.43–0.67						
trans-2-Pentene	0.52–0.9						
Unknown							
Indan	0.25–0.34						
1-Methylindan	0.04–0.17						
2-Methylindan	0.02–0.1						
4-Methylindan	0.01–0.16						
5-Methylindan	0.09–0.3						
Tetralin	0.01–0.14						
Tricresyl phosphate		<0.2	<0.2				

From State of California, Guidelines for Site Assessment, Cleanup, and Underground Storage Tank Closure, Appendix I, 1989; Watts, *Groundwater Monitoring Parameters and Pollution Sources*, 3rd ed., Tables 7.3.1 and 7.3.2, 1989; Kramer and Hayes, *N.J. Geol. Surv. Tech. Memo.*, 87, 87, 1987a.

TABLE 2

Composition of Diesel-, Jet Fuel A-, Diesel Fuel No. 2-, and Fuel Oil No. 2-Based TPH

Constituents	Diesel (wt. %)	Jet fuel A (vol. %)	Diesel fuel no. 2 (vol. %)	Water-soluble-phase fuel oil no. 2 (ppb)
Cycloalkanes				
Cyclopentane		0.59		
Cyclopropane, 1-methyl-2-(3-methylpentyl)				450
cis-1,2-Dimethylcyclohexane				460
Ethylcyclohexane		0.04		2400
1-Ethyl-4-methylcyclohexane				1900
Methyl cyclohexane				950
cis-Octahydropentalene				250
Propylcyclohexane		0.07		
Tetramethylcyclopentane		0.01		
Trimethylcyclohexane				4800
1,1,3-Trimethylcyclohexane		0.03		
Chlorinated aliphatics				
Dibromoethane		0.05		
Ether				
Methyl-*t*-butyl ether				117
Ketone				
Methyl isobutyl ketone				97

TABLE 2 (continued)

Composition of Diesel-, Jet Fuel A-, Diesel Fuel No. 2-, and Fuel Oil No. 2-Based TPH

Constituents	Diesel (wt. %)	Jet fuel A (vol. %)	Diesel fuel no. 2 (vol. %)	Water-soluble-phase fuel oil no. 2 (ppb)
Methyl alkanes				
3,6-Dimethyl undecane				590
6-Ethyl-2-methyl decane				680
2-Methylbutane		0.2–0.26		
3-Methyldecane		0.14		
2-Methylnonane		0.2		
4-Methylnonane		0.22		
3-Methyloctane		2.5		
2-Methyl-6-propyl dodecane				510
2,6,10-Trimethyldodecane	0.45			
2,7,10-Trimethyldodecane				510
2,3,7-Trimethyl octane				800
Methyl alkenes				
3,3-Dimethyl-1-octene				3,100
Monocyclic aromatic hydrocarbons				
Benzene		0.02	Trace	646
Benzene, methyl (1-methylethyl)				490–4,400
Butylbenzene		2		
1,2-Diethylbenzene		0.24		
1,2-Dimethyl-3-propylbenzene		5.4		
1,4-Dimethyl-2-ethylbenzene		0.2		

TABLE 2 (continued)

Composition of Diesel-, Jet Fuel A-, Diesel Fuel No. 2-, and Fuel Oil No. 2-Based TPH

Constituents	Diesel (wt. %)	Jet fuel A (vol. %)	Diesel fuel no. 2 (vol. %)	Water-soluble-phase fuel oil no. 2 (ppb)
Ethylbenzene		0.02	Trace	1,360
1-Ethyl-3-methyl benzene				6,200
1-Methylethyl benzene				12,000–20,000
1-Methylpropyl benzene				2,200
1-Methyl-4-propylbenzene		3.3		
Propylbenzene		3–5		2,500
n-Propylbenzene			Trace	
1,2,4,5-Tetramethylbenzene		9		
Toluene		Trace	Trace	1,680
1,2,3-Trimethylbenzene		6.6		
1,3,5-Trimethylbenzene			Trace	
m-Xylene				3,760
o,p-Xylenes				3,770
Xylenes		0.07	Trace	
Polycyclic aromatic hydrocarbons				
Anthracene			0.013–0.02	
Benzo*[a]*pyrene	0.07 µg/kg			
1,2-Dimethylnaphthalene				540
1,3-Dimethylnaphthalene		0.15		
1-Ethylidene-1*H*-indene				720
Fluorene			0.07–0.1	175
Methylnaphthalene	0.57–0.91			
1-Methylnaphthalene				1,230
2-Methylnaphthalene		0.34		

TABLE 2 (continued)

Composition of *Diesel-*, *Jet Fuel A-*, *Diesel Fuel No. 2-*, and Fuel Oil No. 2-Based TPH

Constituents	Diesel (wt. %)	Jet fuel A (vol. %)	Diesel fuel no. 2 (vol. %)	Water-soluble-phase fuel oil no. 2 (ppb)
Naphthalene	0.13	0.14	0.14–0.11	
Phenanthrene			0.26–0.3	296
Pyrene				65
Simple alkanes				
Decane		16.5		375
n-Decane	0.5–2			
n-Docosane	<0.2			
Dodecane		0.7		
n-Dodecane	0.96–11			
n-Eicosane	0.23–3			
n-Heneicosane	1			
n-Heptadecane	1.2–6			
Hexadecane				350
n-Hexadecane	1.2–6			
n-Nonadecane	0.53–4			
n-Nonane	0.1			
n-Octadecane	0.82–5			
Pentadecane				1,170
n-Pentadecane	1–7			
7-Propyl *tridecane*				925
n-Tetradecane	1.1–9			
Tridecane		0.5		1,030
n-Tridecane	1.1–10			
Undecane		36		590
n-Undecane	0.98–9			

TABLE 2 (continued)

Composition of Diesel-, Jet Fuel A-, Diesel Fuel No. 2-, and Fuel Oil No. 2-Based TPH

Constituents	Diesel (wt. %)	Jet fuel A (vol. %)	Diesel fuel no. 2 (vol. %)	Water-soluble-phase fuel oil no. 2 (ppb)
Unknown				
Alkyl nitrate			0.2	
Methylindane		0.3		
Pentacozane				1,380

From State of California, Guidelines for Site Assessment, Cleanup, and Underground Storage Tank Closure, Appendix I, 1989; Watts, *Groundwater Monitoring Parameters and Pollution Sources,* 3rd ed., Tables 7.3.1 and 7.3.2, 1989; Kramer and Hayes, *N.J. Geol. Surv. Tech. Memo.*, 87, 87, 1987b.

diesel, jet fuel, and water-soluble components of gasolines and fuel oil. Units of quantification used in the table are the same as those provided in the original source.

Most of the these analyses were performed on fresh petroleum products. Environmental media are not expected to contain these same distributions of components due to volatilization following releases, biodegradation, selective migration through soils and into ground water, and other processes. These processes must be considered when identifying surrogates for TPH at a particular site.

It is clear from Tables 1 and 2 that the composition of TPH varies significantly. For instance, gasoline products contain more straight-chain hydrocarbons than do diesel products. This will affect both the movement of the products in the environment and their toxicity. A greater number and variety of components have been identified in gasoline than in other petroleum products, suggesting complex characteristics affecting movement in the environment and toxicity, as well as a wide range of options for evaluating these characteristics.

The following sections provide available information on the components identified in Tables 1 and 2. This information can be used to evaluate the effects of weathering and movement in the environment on the composition of TPH at release sites and the toxicity of TPH.

III. CHEMICAL AND PHYSICAL PROPERTIES

Information about chemical and physical properties is presented in Table 3 for the TPH components identified in Tables 1 and 2. The following properties are included in the table: molecular weight, water solubility, specific gravity, vapor pressure, Henry's law constant, diffusivity, organic carbon/water partition coefficient (K_{oc}), octanol/water partition coefficient (log K_{ow}), fish bioconcentration factor (BCF), and surface-water half-life. The information was obtained from readily available sources and does not represent an exhaustive search of the literature. Rather, it is adequate for appropriate identification of surrogates to represent the weathering and movement of petroleum hydrocarbons in the environment. The information also illustrates what is readily available in the open scientific literature.

Solubility is an important property affecting constituent migration in soils, ground water, and surface water. Solubility is expressed in terms of the number of milligrams of a constituent that can be dissolved in 1 l of water (mg/l) under standard conditions of 25°C and one atmosphere of pressure (atm). The higher the value of solubility, the greater the tendency of a constituent to dissolve in water. For inorganic constituents, solubility depends on the form of the constituents.

Volatility is another important property affecting the mobility and persistence of organic constituents and several forms of inorganics. Henry's law constant (H) is an indication of the tendency of a constituent to volatilize, or "partition," from the

TABLE 3

Chemical and Physical Properties of TPH Components

Constituents	Molecular wt.	Water solubility (mg/L 25°C)	Specific gravity	Vapor pressure (mmHg 25°C)	Henry's law constant (atm-m³/mol 25°C)	Diffusivity (cm²/s)	K_{oc} (ml/g)	Log K_{ow}	Fish BCF (L/kg)	Surface-water $T_{1/2}$ (days) Low high
Alcohols										
Ethyl alcohol	46.07	280,000	0.789	59	1.2E – 05	0.12368	0.3	3.1	0.34	
Methyl alcohol	32	300 ,000		130	2.0E – 05	0.16211	0.1	1.5	2.3	
t-Butyl alcohol	74.1		0.788	42		0.09752		0.37		
Cycloalkanes										
Cyclopentane	70.14	160	0.751	42.4	1.9E + 0.1					
Methyl cyclohexane	98.19	14	0.77	6.18	4.3E + 01					
Cycloalkenes										
Cyclohexene	84.16	55 (20°C)	0.779	77 (20°C)						
Cyclopentene	68.12		0.77							
Chlorinated aliphatics										
1,2-Dichloroethane	99	7,986–8,650	1.23	87	1.3E – 03	0.09451	65	1.48–2.13	5.6	28–180
Dibromoethane	187.88	4.31 (30°C)	2,701	17 (30°C)						
1,1-Dichloroethane	99	5060	1.1757	182.1	5.9E – 03	0.0959	30.2	1.79		
Ether										
Methyl-*t*-butyl ether	88	4800	0.74	250	5.9E – 03	0.10172	41	1.2	1.5	28–180
Ketone										
Methyl isobutyl ketone	100.2	20,400	0.8017	14.5	9.4E – 05	0.07588	19–106	1.19		
Methyl alkanes										
2,3-Dimethylbutane	86.7	19.1		31.3	1.3E + 02					
2,3-Dimethylpentane	100.21	5.25		9.18	1.8E + 02					
2,4-Dimethylpentane	100.21	5.5		13.1	3.0E + 02					
3,3-Dimethylpentane	100.21	5.94		11	1.9E + 02					
2-Methylheptane	114.23									
3-Methylheptane	114.23	0.792		2.6	3.8E + 02					
4-Methylheptane	114.23									

TABLE 3 (continued)

Chemical and Physical Properties of TPH Components

Constituents	Molecular wt.	Water solubility (mg/L 25°C)	Specific gravity	Vapor pressure (mmHg 25°C)	Henry's law constant (atm-m³/mol 25°C)	Diffusivity (cm²/s)	K_{oc} (ml/g)	Log K_{ow}	Fish BCF (L/kg)	Surface-water $T_{1/2}$ (days)
										Low high
2-Methylhexane	100.21	2.54		8.78	3.5E + 02					
3-Methylhexane	100.21	4.95		8.21	2.4E + 02					
4-Methyloctane	128.26	0.115		0.903	1.0E + 03					
2-Methylpentane	86.17	13	0.654	28.2	1.7E + 02					
3-Methylpentane	86.17	13.1	0.6645	25.3	1.7E + 02					
2,2,4-Trimethylhexane	128.26									
2,2,5-Trimethylhexane	128.26	1.15		2.21	3.5E + 02					
2,3,3-Trimethylhexane	128.26									
2,3,5-Trimethylhexane	128.26									
2,4,4-tTrimethylhexane	128.26									
2,2,3-Trimethylpentane	114.23									
2,2,4-Trimethylpentane	114.23	2.44		6.56	3.3E + 02					
2,3,3-Trimethylpentane	114.23									
2,3,4-Trimethylpentane	114.23	2.3		3.6	1.9E + 02					
Methyl alkenes										
2-Methyl-1-butene	70.14		0.65							
2-Methyl-2-butene	70.14		0.668							
3-Methyl-1-butene	70.14	130	0.648	120	5.5E + 01					
2-Methyl-1-pentene	86.16	78	0.6817							
2-Methyl-2-pentene	86.16									
3-Methyl-*cis*-2-pentene	86.16									
3-Methyl-*trans*-2-pentene	86.16		0.67							
4-Methyl-*cis*-2-pentene	86.16		0.67							
4-Methyl-*trans*-2-pentene	86.16									
Monocyclic aromatic hydrocarbons										
Benzene	78	1780	0.88	95	5.5E – 03	9.30E – 02	49–100	1.56–2.15	5.2	5
Butylbenzene	134		0.86	1 (23°C)			1500			
n-Butylbenzene	134	50	0.86	1 (23°C)	1.3E + 00					
sec-Butylbenzene	134	30.9	0.87	1.5 (20°C)	1.4E + 00					
t-Butylbenzene	134	34	0.862	1.1 (20°C)	1.2E + 00					
1,2-Diethylbenzene	136						1500			
1,3-Diethylbenzene	136						1500			
Ethylbenzene	106	152–208	0.87	9.5	8.7E – 03	6.70E – 02	95–260	3.05–3.15	37.5	3
Isobutylbenzene	134.2	10.1		0.248	3.3E + 00					
o/p-Isopropylbenzene	120	50 (20°C)	0.862	3.2 (20°C)	1.0E – 02			3.66		2
n-Pentylbenzene	149						2520			

TABLE 3 (continued)

Chemical and Physical Properties of TPH Components

Constituents	Molecular wt.	Water solubility (mg/L 25°C)	Specific gravity	Vapor pressure (mmHg 25°C)	Henry's law constant (atm-m³/mol 25°C)	Diffusivity (cm²/s)	K_{oc} (ml/g)	Log K_{ow}	Fish BCF (L/kg)	Surface-water $T_{1/2}$ (days) Low high
Propylbenzene	120.2	60		0.449	7.0E – 01					
n-Propylbenzene	120	60 (15°C)	0.862	2.5 (20°C)	5.6E – 03 (15°C)			3.57–3.68		
1,2,3,4-Tetramethylbenzene	215.9	4.31		0.00876	2.6E – 01		1500			
1,2,3,5-Tetramethylbenzene	215.9	3.5		0.0186	5.9E – 01		1500			
1,2,4,5-Tetramethylbenzene	134.2	3.48		0.0659	2.5E + 00		1500			
Toluene	92	490–627	0.87	28	6.7E – 03	7.80E – 02	115–150	2.11– 2.8	10.7	4
1,2,3-Trimethylbenzene	120						884			
1,2,4-Trimethylbenzene	120	57 (20°C)	0.88	1.4	3.9E – 01 (20°C)		1600	3.4	230	7
1,3,5-Trimethylbenzene	120	64	0.865	1.4	3.7E – 01	1.60E + 03	3.4	230		
m-Xylene	106	173	0.8684	10	6.3E – 03		1585	3.2		
o-Xylene	106	204	0.87596	10	5.4E – 03		129	2.77–3.16		
p-Xylene	106	200	0.85665	10	6.3E – 03		204	3.15		
Xylenes	106	162—200	0.87	6.6—8.8	6.3E – 03	7.20E – 02	128—1,580	2.77—3.2	132	7
Polycyclic aromatic hydrocarbons										
Anthracene	178	0.030— 0.1125	1.24	1.7E – 5— 1.95E – 4	6.5E – 05	5.90E – 02	16,000— 26,000	4.34—4.54	30	0.071 0.024
Benzo*[a]*pyrene	252	0.0038— 0.004	1.35	5.5E – 09	<2.4E – 6	4.70E – 02	398,000— 1,900,000	5.81—6.50	30	0.015 0.046
Benzo*[b]*fluoranthene	252	0.0012	. ND	5.0E – 07	1.2E – 05	4.40E – 02	550,000	6.57	ND	0.36
Benzo*[e]*pyrene	252					4.70E – 02				
1,2-Dimethylnaphthalene	158						4230			
1,3-Dimethylnaphthalene	158						4230			
Fluoranthene	202	0.206— 0.373	1.25	0.000005	1.7E – 02	42,000	5.22	1.150	0.875	2.6
Fluorene	166	1.66—1.98	1.2	1E – 3— 1E – 2	2.1E – 04	5.70E – 02	5000	4.12—4.38	30	32
Methylnaphthalene	142	27								
1-Methylnaphthalene	142	28	1.025	ND	ND	ND	ND	ND	129	ND
2-Methylnaphthalene	142	25	1.001	0.045	3.4E – 04	6.20E – 02	7,400— 8,500	3.86—4.11	190	ND
Naphthalene	128	30—34	1.16	2.3E – 1— 8.7E – 1	4.6E – 04	8.20E – 02	550— 3,160	3.2—4.7	10.5	0.5
Phenanthrene	178	0.71—1.29	1.18	0.00068	2.6E – 05	5.40E – 02	5250— 38,900	4.2—4.6	30	0.125 1.04
Pyrene	202	0.013— 0.171	1.27	6.85E – 07— 2.5E – 05	1.1E – 05	5.00E – 02	46,000— 135,000	4.88—5.32	30	0.028 0.085

TABLE 3 (continued)

Chemical and Physical Properties of TPH Components

Constituents	Molecular wt.	Water solubility (mg/L 25°C)	Specific gravity	Vapor pressure (mmHg 25°C)	Henry's law constant (atm-m³/mol 25°C)	Diffusivity (cm²/s)	K_{oc} (ml/g)	Log K_{ow}	Fish BCF (L/kg)	Surface-water $T_{1/2}$ (days) Low high
Simple alkanes										
n-Butane	58.13	61	0.6	1.82E + 03	9.6E – 01					
Decane	148.28	0.008								
n-Decane	148.28	0.052		0.175	7.0E + 02					
Dodecane	170.33	0.0037		0.0157	7.5E + 02					
n-Dodecane	170.33									
n-Eicosane	282.6	0.0019		2.67E – 06	2.9E – 01					
n-Heptane	100.21	3		0.06872	2.3E + 02					
n-Hexadecane	226.44	0.00628		0.000917	2.3E + 01					
n-Hexane	86	18 (20°C)	0.66	1.2E – 2 (20°C)	7.7E – 01	7.50E – 02	890	2.77	ND	ND
Isobutane	58.13	48.19		357	1.2E + 02					
Isopentane	72.15	48		92.6	1.4E + 02					
n-Nonane	128.26	0.07		0.571	5.0E + 02					
n-Octadecane	254.4	0.0021		2.50E – 05	2.9E + 00					
n-Octane	114.23	0.66		1.88	3.0E + 02					
n-Pentane	72.15	35		68.4	1.3E + 02					
Propane	44.09	63	0.58	8.5						
n-Tetradecane	190.38	0.00696		0.00127	1.1E + 02					
Undecane	156.32	0.044		0.0522	1.9E + 03					
n-Undecane	156.32									
Simple alkenes										
2-Butene		210								
cis-2-Butene	56.1		0.64							
trans-2-Butene	56.1		0.64							
cis-3-Heptene	98	9								
trans-3-Heptene	98									
cis-2-Hexene	84	50	0.86							
trans-2-Hexene	84	50	0.86							
cis-3-Hexene	84									
trans-3-Hexene	84									
1-Pentene	70.14	150		85	4.0E + 01					
2-Pentene	70.14	203		66	2.3E + 01					
cis-2-Pentene	70.14									
trans-2-Pentene	70.14									

From Bidleman, T. F. *et al.* (1986); Budavari, S. (1989); Dixon, D. and E. Rissmann (1985); Howard, P. H. (1989); Howard, P. H. (1990); Howard, P. H. *et al.* (1991); Lyman, W. J. *et al.* (1982); Mackay, D. *et al.* (1983); Mackay, D. and W. Y. Shiu (1981); Montgomery, J. H. and L. M. Welkom (1990); Shen, T. J. (1982); Strenge and Peterson (1989); U.S.EPA (1991); Verschueren, K. (1983).

aqueous or water phase to the vapor phase and is dependent on the vapor pressure and solubility of the constituent. Organic constituents having H values of 10^{-3} atm-m^3/mol or greater tend to volatilize from water; those with H values $<10^{-3}$ atm-m^3/mol may volatilize from water, but other processes such as adsorption to soil or sediment may be more important (Howard, 1989). In evaluating volatilization from water used within the home, U.S. Environmental Protection Agency (EPA) guidance (1991) recommends including constituents with an H of $>10^{-5}$ atm-m^3/mol and a molecular weight of <200 g/mol.

The potential for a constituent to adsorb to soil and sediment particles affects migration through soil and aquifer materials as well as migration from surface water to sediments. The potential for adsorption usually is expressed in terms of a partition coefficient, K_d. A K_d is the ratio of the concentration of adsorbed constituent to the concentration of aqueous-phase constituent and, although a unitless quantity, typically it is reported in units of milliliters per gram (ml/g). Higher values of K_d indicate greater potential for the constituent to sorb to soil, sediment, and aquifer materials. This partition coefficient may be determined empirically or estimated using constituent-specific and sediment- or soil-specific parameters. The parameters used to calculate K_d for organic constituents are the organic carbon/water partition coefficient (K_{oc}), which measures the selective affinity for soil organic carbon vs. water, and the fraction of organic carbon (f_{oc}) in soil, because K_d is commonly expressed as the product of the K_{oc} and f_{oc} (EPA, 1989a).

The octanol/water partition coefficient (K_{ow}) is a measure of the selective affinity for *n*-octanol vs. water. The fish BCF is used as an indication of the ability of a constituent to bioaccumulate in fish.

Persistence is the "lasting power" of constituents and is commonly expressed in terms of half-lives ($t_{1/2}$) for specific environmental media. A half-life is the time required for one half of the mass of a compound to be transformed into other constituents.

IV. TOXICITY VALUES

For purposes of quantitative risk assessment, the inherent toxicity of each chemical must be reduced to numerical values. A distinction is made between carcinogenic and noncarcinogenic effects. For potential carcinogens, the current regulatory guidelines (EPA, 1989b) use an extremely conservative approach in which it is assumed that any level of exposure to a carcinogen could hypothetically cause cancer. This is contrary to the traditional toxicological approach, in which finite thresholds are identified below which toxic effects are not expected to occur. This traditional approach still is applied to noncarcinogenic health effects.

Identification of constituents as known, probable, or possible human carcinogens is based on an EPA weight-of-evidence classification scheme in which chemicals are systematically evaluated for their ability to cause cancer in mammalian species and conclusions are reached about the potential to cause cancer in humans. The EPA classification scheme (EPA, 1989b) contains six classes based on the weight of available evidence, as follows:

A: known human carcinogen

B1: probable human carcinogen, limited evidence in humans

B2: probable human carcinogen, sufficient evidence in animals and inadequate data in humans

C: possible human carcinogen, limited evidence in animals

D: inadequate evidence to classify

E: evidence of noncarcinogenicity.

Some constituents in class D may have the potential to cause cancer, but adequate data are not currently available to change the classification.

The toxicity value used to describe the potency of a class A, B1, B2, or C carcinogen is the cancer slope factor (CSF). The slope factor is generated by the EPA through the use of a mathematical model that extrapolates from the high doses in animal studies to the low doses characterizing human exposures. The CSF represents the 95% upper confidence limit on the slope of the dose-response curve generated by the model.

For many noncarcinogenic effects, protective mechanisms must be overcome before the effect is manifested. Therefore, a finite dose (threshold), below which adverse effects will not occur, is believed to exist for noncarcinogens. For a given constituent, the dose that elicits no effect when evaluating the most sensitive response (the adverse effect that occurs at the lowest dose) in the most sensitive species is combined with uncertainty factors ("safety" factors, "modifying" factors) to establish an acceptable dose (toxicity value) for noncarcinogenic effects. Acceptable doses that are sanctioned by the EPA are called verified reference doses (RfDs) for oral or inhalation exposure or reference concentrations (RfCs) for inhalation exposure.

Most federal and state regulatory agencies expect that slope factors, cancer classifications, RfDs, and RfCs will be taken from the Integrated Risk Information System (IRIS, 1992) or, in the absence of IRIS data, the EPA Health Effects Assessment Summary Tables (HEAST) (EPA, 1992). Potential alternatives include in-depth review of the literature pertaining to toxicity of a particular constituent, resulting in independent development of a toxicity value, or estimation of toxicity based on structure-activity relationships. However, most agencies lack the time or resources to evaluate such efforts. Thus IRIS and HEAST are the preferred sources of information. IRIS is an online data base containing up-to-date health risk and regulatory information provided by the EPA and contains only toxicity values that have been verified by the RfD or Carcinogen Risk Assessment Verification Endeavor Workgroups. HEAST is a tabular presentation, also prepared by the EPA, of interim RfDs and slope factors. HEAST is updated periodically. Available toxicity information from IRIS and HEAST is provided in Table 4.

Toxicity values were available for only a small number of the components identified in Tables 1 and 2. Although significant additional information is available in the literature for a number of the other components, many regulatory agencies are reluctant to accept toxicity values derived on the basis of the literature if confirmatory information is not available on either IRIS or HEAST. Therefore, from the perspective of real-world applications for most petroleum release sites, the information provided here is most pertinent to selection of surrogate compounds for TPH.

V. DISCUSSION

The composition of released petroleum products varies significantly, depending on the source, weathering of the product over time, and differential movement of the components in the environment. For most release sites, detailed information about the composition of TPH will not be available. Information presented in Tables 1 and 2 can be used to determine roughly what the initial composition of TPH in the released product might have been, thereby providing a starting point for evaluation of petroleum product releases. The next important step is to consider the effects of weathering on the ultimate composition of TPH remaining in the environment as a result of the release. Information presented in Table 3 describing chemical and physical properties of TPH components can contribute to evaluation of the effects of weathering and to consideration of the impact of fate and transport processes on the composition of TPH both close to and away from the original release point. Surrogate compounds can be selected to depict movement of TPH (or fractions of TPH) in the environment. Information provided in Table 4 can be used to identify one or more surrogate compounds to represent the toxicity of TPH associated with a particular release.

When properly integrated, the information presented in this article can contribute to selection of surrogate compounds that represent the movement of site-specific TPH in the environment and the toxicity of TPH that reaches human and ecological receptors. This approach can contribute to meaningful decision making about regulation and remediation of petroleum releases to the environment.

TABLE 4
Reference Doses, U.S. EPA Cancer Classifications, and Cancer Slope Factors for TPH Components

Constituents	RfDi^a (mg/kg/d) subchronic	RfDi^a (mg/kg/d) chronic	RfDo^b (mg/kg/d) subchronic	RfDo^b (mg/kg/d) chronic	Cancer class	CSFo^c (mg/kg/d)^–1	CSFi^d (mg/kg/d)^–1
Alcohols							
t-Butyl alcohol	NA	NA	1.0E + 00	1.0E – 01	D	NC	NC
Methyl alcohol	NA	NA	5.0E + 00	5.0E – 01	D	NC	NC
Cycloalkanes							
Dibromoethane	NA	NA	NA	NA	B2	8.5E + 01	7.7E – 01
1,1-Dichloroethane	5.0E + 00	5.0E – 01	1.0E + 00	1.0E – 01	B2	1.4E – 01	NA
Ethylene dibromide	NA	NA	2.0E – 01	2.0E – 02	C	8.4E – 02	NA
Ether							
Methyl-*t*-butyl ether	1.4E + 00	1.4E – 01	NA	NA	D	NC	NC
Monocyclic aromatic hydrocarbons							
Benzene	NA	NA	NA	NA	A	2.9E – 02	2.9E – 02
Ethylbenzene	2.9E – 01	2.9E – 01	1.0E + 00	1.0E – 01	D	NC	NC
eip-Isopropylbenzene	2.6E – 02	2.6E – 03	3.0E – 02	4.0E – 02	D	NC	NC
Toluene	5.7E – 01	1.1E – 01	2.0E + 00	2.0E – 01	D	NC	NC
Xylenes	NA	NA	4.0E + 00	2.0E + 00	D	NC	NC

TABLE 4 (continued)

Reference Doses, U.S. EPA Cancer Classifications, and Cancer Slope Factors for TPH Components

Constituents	RfDi[a] (mg/kg/d) subchronic	RfDi[a] (mg/kg/d) chronic	RfDo[b] (mg/kg/d) subchronic	RfDo[b] (mg/kg/d) chronic	Cancer class	CSFo[c] (mg/kg/d)^–1	CSFi[d] (mg/kg/d)^–1
Polycyclic aromatic hydrocarbons							
Anthracene	NA	NA	3.0E + 00	3.0E – 01	D	NC	NC
Benzo*[a]*pyrene	NA	NA	NA	NA	B2	7.3E + 00	6.1E + 00
Fluoranthene	NA	NA	4.0E – 01	4.0E – 02	D	NC	NC
Fluorene	NA	NA	4.0E – 02	4.0E – 02	D	NC	NC
Naphthalene	NA	NA	4.0E – 02	4.0E – 02	D	NC	NC
Pyrene	NA	NA	3.0E – 01	3.0E – 02	D	NC	NC
Simple alkanes							
n-Hexane	5.7E – 02	5.7E – 02	6.0E – 01	6.0E – 02	D	NC	NC

[a] RfDi = inhalation reference dose.

[b] RfDo = oral reference dose.

[c] CSFo = oral cancer slope factor.

[d] CSFi = inhalation cancer slope factor.

From U.S. EPA HEAST, 1992, and IRIS, 1992.

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