California Environmental Protection Agency

Department of Toxic Substances Control
Edwin Lowry, Director

State of California
Gray Davis, Governor

Oil Exploration and Production Wastes Initiative

Department of Toxic Substances Control   Hazardous Waste Management Program
Statewide Compliance Division

OIL EXPLORATION AND PRODUCTION WASTES INITIATIVE

Published by

Department of Toxic Substances Control
Hazardous Waste Management Program
Statewide Compliance Division

Sacramento
May 2002

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Acknowledgement

The Statewide Compliance Division wishes to thank all participating oil production facilities for the outstanding cooperation accorded SCD staff during the survey and sampling stages of this research project. SCD also acknowledges the staff of the U.S. EPA Office of Solid Waste, Washington D.C., and the staff of the California Department of Conservation, Division of Oil, Gas and Geothermal Resources, Sacramento, California, for their valuable contributions to this project via phone conversations, meetings, and sharing of materials. Particular thanks are extended to the SCD sampling team and participating laboratories for their assistance in conducting sampling and analysis.

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LIST OF ACRONYMS

API	American Petroleum Institute
BTX	Benzene, Toluene, Xylene
CA	California (State of)
CCR	California Code of Regulations
CDC	California Department of Conservation
CFR	Code of Federal Regulations
DHS	Department of Health Services (State of California)
DL	Detection Limit
DOGGR	Division of Oil, Gas and Geothermal Resources (within CDC)
DTSC	Department of Toxic Substances Control (State of California)
E&P	Exploration and Production
FR	Federal Register
HWMP	Hazardous Waste Management Program (within DTSC)
IOGCC	Interstate Oil and Gas Compact Commission
ND	Not Detected
NPDES	National Pollution Discharge Elimination System
RCRA	Resource Conservation and Recovery Act
RT	Regulatory Threshold
SCD	Statewide Compliance Division (of the Hazardous Waste Management Program of DTSC)
STLC	Soluble Threshold Limit Concentration
SVOCs	Semi-Volatile Organic Compounds
TCLP	Toxicity Characteristic Leaching Procedure
TPH	Total Petroleum Hydrocarbons
TTLC	Total Threshold Limit Concentration
U.S. EPA	United States Environmental Protection Agency
UCL	Upper Confidence Interval Limit
VOCs	Volatile Organic Compounds
WSPA	Western States Petroleum Association

EXECUTIVE SUMMARY

The Oil Exploration and Production (E&P) Wastes Initiative described in this document was a field research project conducted by the Department of Toxic Substances Control, Hazardous Waste Management Program, Statewide Compliance Division, during the year 2000/2001, and was funded by a grant from the U.S. EPA. The scope of the project was to characterize E&P wastes, and based on the findings, determine if the wastes are being managed properly in California. SCD collected and analyzed eighty-two waste samples, not including field blank samples. The wastestreams represented by the samples were: produced water; drilling waste; oily sludge; and foam treatment waste (a type of workover waste). The parameters of analysis were: pH; flash point; total reactive sulfides; aquatic toxicity; total petroleum hydrocarbons; metals; benzene, toluene, xylenes; volatile organic compounds; and semi-volatile organic compounds.

Currently, E&P wastes are managed as non-hazardous solid wastes under Federal law, pursuant to the E&P exemption codified in Title 40 Code of Federal Regulations (40 CFR), Section 261.4(b)(5), and included, with limitations, in Title 22 California Code of Regulations (22 CCR) Sections 66261.4(b)(2) and 66261.24(a)(1). The exemption applies in California if the waste displays the toxicity characteristic for hazardous waste based solely on the Toxicity Characteristic Leaching Procedure (TCLP), as provided under 22 CCR, Section 66261.24.

Overall, the wastestreams sampled were not found to be hazardous based on the data obtained and the statistical interpretation of that data; however, isolated cases are discussed where the E&P wastes displayed California hazardous waste characteristics. The study concludes that some E&P wastes may exhibit California hazardous waste characteristics not covered under the Federal exemption, and should be managed as hazardous wastes under State law. Guidance is given to the generators to properly characterize E&P wastes and dispose of those wastes in accordance with all applicable State and Federal laws and regulations.

I. INTRODUCTION

This report summarizes the findings of the Oil Exploration and Production Wastes Initiative, a field research project conducted by the Department of Toxic Substances Control (DTSC), Hazardous Waste Management Program (HWMP), Statewide Compliance Division (SCD), during December 2000 through August 2001. The purpose of the initiative was to obtain scientific data that would enhance DTSC's knowledge of the characteristics of oil exploration and production (E&P) wastes, and determine, based on the data obtained, whether those wastes are being properly managed in accordance with standards imposed under Federal and State law.

DTSC protects public health and the environment by regulating the generation, storage, transportation, and disposal of hazardous wastes within the State of California. To determine the applicability of DTSC's program to the regulation of E&P wastes, samples of E&P wastes collected as part of this initiative were tested for characteristics of hazardous waste under Federal and State law. The data obtained from sample analysis are interpreted and discussed in light of criteria for identifying hazardous waste, as codified in Title 40, Code of Federal Regulation (40 CFR), Sections 261.10 et seq., and in Title 22, California Code of Regulations (22 CCR), Article 3, Sections 66261.20 et seq.

This study is not inclusive of all E&P wastes. Resources allocated for this project were focused on the study of those wastestreams that, due to volume or other factors listed in this summary, could present a greater threat to public health and the environment if determined to be hazardous under State law. Wastes discussed in this report are produced water, drilling waste, oily sludge waste, and foam treatment waste from a foam treatment operation. This report contains a limited amount of data pertaining to workover wastes, and does not contain any information pertaining to wastes produced by natural gas exploration and production.

This report may be used as a general guidance document, indicative of constituents that may be present in E&P wastes. Because facility operations and geological characteristics of oil-bearing strata may vary from region to region, the wastes produced may also exhibit local differences in composition. It ultimately remains the facility's responsibility to analyze its waste and, through proper knowledge of the waste's characteristics, manage that waste in accordance with all applicable Federal and State environmental laws and regulations.

II. SCOPE OF THE PROJECT

California is the country's fourth largest oil producer, with sixteen counties that produce crude oil, 45,597 producing oil wells and 311.5 million barrels of oil produced in 1999 (CDC, 2000). Oil production in California generates significant amounts of waste each year, which is mostly managed as non-hazardous solid waste under the E&P exemption discussed in the Regulatory Background section of this document. A review of available published data indicated that E&P wastes might contain constituents of concern to U.S. EPA and DTSC. Therefore, the scope of the initiative was to characterize E&P wastes, with a view towards determining any hazardous waste characteristics and, based on the data obtained, determine if E&P wastes are being managed properly in California in accordance with standards imposed under Federal and State laws. Due to limitations of the study, the primary focus was placed on characterizing those E&P wastestreams that, if found to be hazardous, would present a greater threat to public health and the environment. Other, smaller volume wastestreams associated with the oil production industry remain of interest to DTSC and may be addressed in a future study.

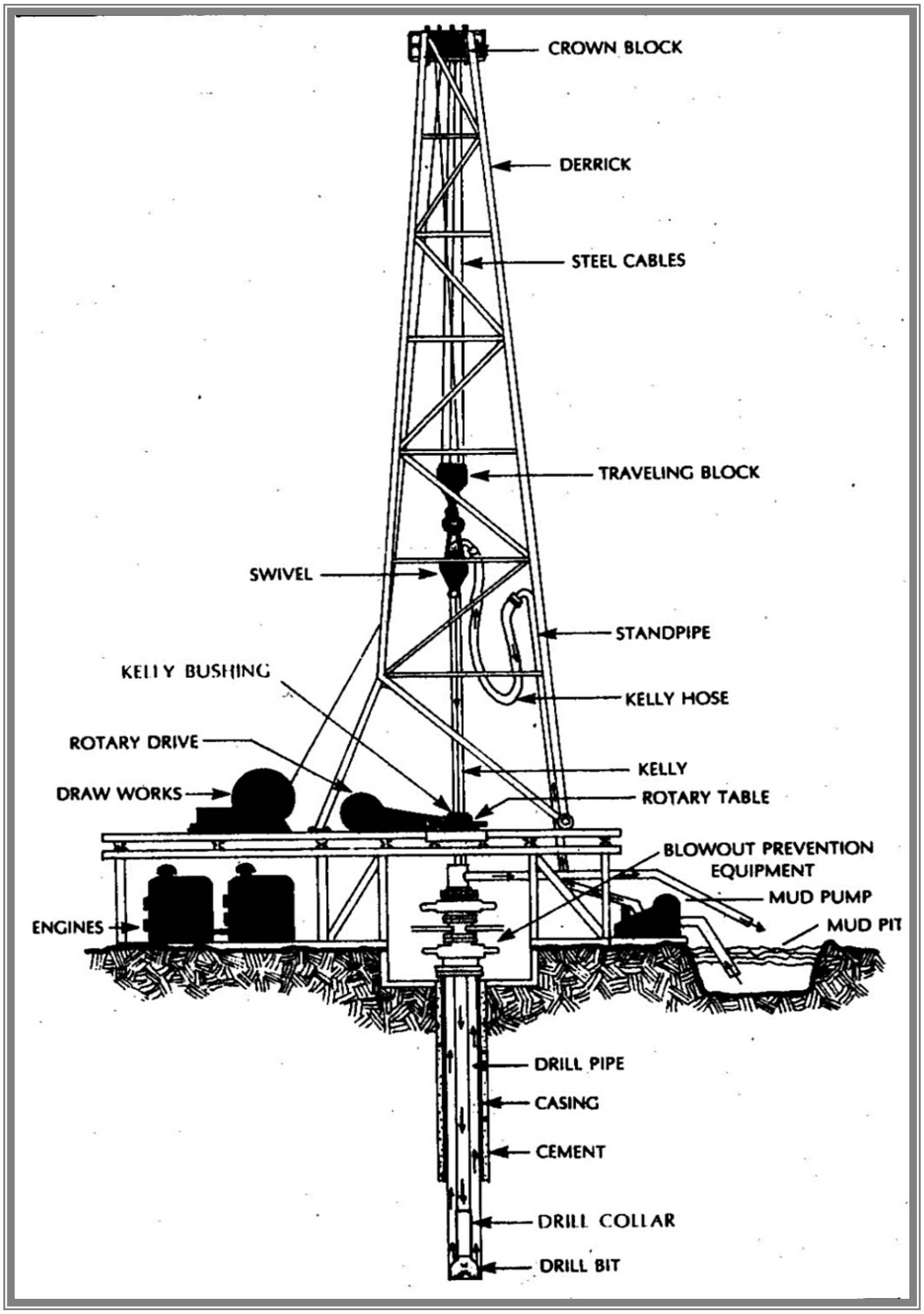
III. OIL PRODUCTION IN CALIFORNIA: KEY TERMS AND CONCEPTS

Key terms and concepts related to oil production and used throughout this report are summarized below.

<u>Oil exploration</u>
Oil exploration encompasses activities undertaken to identify and access geological formations that contain oil. A common example of such an activity is drilling, or the creation of a wellbore that perforates the ground and reaches the subsurface strata that house an oil reservoir. Drilling for both oil and natural gas employs similar techniques and is accomplished by use of equipment that can cut through soil and rock. A multi-component structure called the drilling rig (see Figures 1 and 2) is set up and used to control and operate the downhole drilling equipment. Drilling fluid (also called drilling mud) is pumped through the drilling pipe connected to a rotary cutting device, called the drilling bit. The purpose of the drilling fluid is to lubricate the bit as it cuts through the soil, prevent the wellbore from caving in, and float the soil and rock cuttings up to the ground surface.

Locations where drilling takes place are referred to as drilling sites, and are the sources of drilling wastes.

Figure 1: Schematic Representation of a Drilling Rig



Source: CDC, DOGGR, 2001.

Figure 2: Digital Photograph of a Drilling Rig

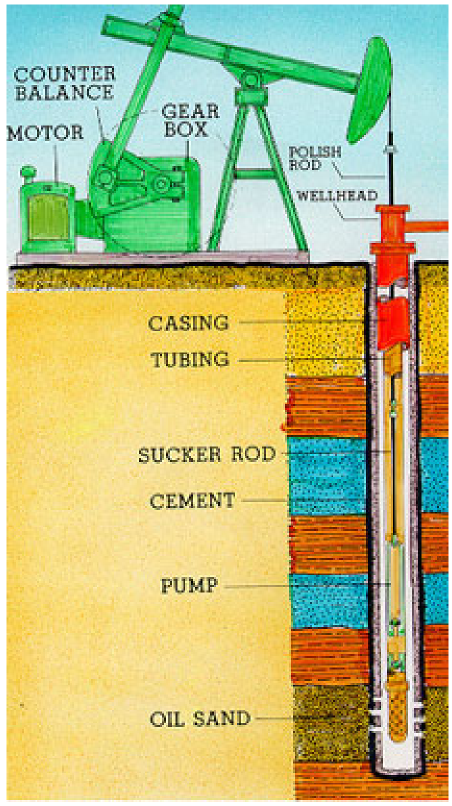
Oil well

An oil well can be described as a wellbore that has been completed and prepared for production. Not every new well becomes a producing well. If no oil is found, the well is abandoned through a process called well abandonment. If oil is found in economically feasible amounts, the well is completed, in a process known as well completion. In 1999 in California, 1,752 new wells were drilled, out of which 1, 379 wells were completed. Non-producing new wells and wells that have been depleted are plugged and abandoned. 1, 307 wells were abandoned in California in 1999 (CDC, 2000).

A first step in well completion is the installation of casing, or hollow tubing that preserves the structural integrity of the wellbore by isolating it from the surrounding strata. Casing is cemented inside the wellbore and houses the production tubing later installed to pump and transport oil from the producing formation to the surface. The above-surface portion of a well is the pumping unit, which may be a mechanical or a more sophisticated hydraulic or electrical device. Figure 3 is a representation of a mechanical pumping unit.

In a well abandonment operation, the casing is plugged with alternating layers of cement and drilling fluid. Wastes produced by both completion and abandonment operations are usually leftover cement and drilling fluid.

Figure 3: Oil Well with Mechanical Pumping Unit



Source: DOGGR, 2000

<u>Oil production</u>
Oil production encompasses those activities that are associated with the extraction of oil from the ground, and subsequent processing that takes place to remove excess water and natural gas where applicable, and render a crude oil product sellable to a refinery. According to oil production industry representatives interviewed during the course of this study, crude oil is typically processed to contain less than three percent water at time of shipment to the refinery.

<u>Production facility</u>
A production facility is the site where oil production, described above, takes place. Crude oil may be extracted on location or brought to the production facility from offsite wells via pipeline or truck. Wastes such as produced water

and oily sludge are generated at production facilities. Depending on the type of operation, other E&P wastes such as drilling and workover wastes may also be generated at production facilities.

Well workover

A well workover is an intervening procedure performed as general maintenance or to restore production in a failing well. Workovers may be performed to remove unwanted materials that tend to accumulate at the base of production piping, such as salt scale, paraffin, or sand. Examples of workovers include acidizing and foam treatment operations, which are designed to remove scale and paraffin, respectively. A foam treatment operation is a procedure whereby soap is injected into the well to dissolve paraffin deposits that hinder production. Other workovers such as fracturing operations may be performed to create cracks in the producing formation and improve oil flow into the well. Workovers generate workover wastes.

For a more extensive list of terms and concepts related to oil production, please see the Glossary of Terms section at the end of this document.

IV. OVERVIEW OF E&P WASTES

The term "E&P wastes" is used to describe wastes generated by exploration, development, and production activities related to oil production, including the extraction of crude oil from the ground, and subsequent purification processes that take place to remove co-produced excess water and other unwanted materials. The oil production industry typically divides E&P wastes into three categories: produced water; drilling wastes; and associated wastes.

Produced water is formation water that is co-produced with the oil, and it constitutes the E&P wastestream generated in the largest amounts. Drilling waste is the second largest volume waste generated by the oil production industry. Because drilling is essentially the same for both oil and natural gas, published data referenced in this report combine the volume of drilling waste generated in California during both types of operations. The third category, associated wastes, consists of lower volume wastes generated in conjunction with oil production. Grouped in this category are the following types of wastes:

- Oily sludges;
- Workover wastes;
- Well completion and well abandonment wastes (such as left over cement and drilling fluid);
- Other small volume wastes associated with oil production.

For a further discussion of E&P wastes, please refer to the Wastestreams Sampled section of this report.

V. REGULATORY BACKGROUND

E&P wastes intrinsic to oil production are currently exempt from regulation as hazardous wastes under Federal law, pursuant to 40 CFR, Section 261.4(b)(5). As stated by U.S. EPA, wastes intrinsic to oil production, such as those segregated from the production stream and other wastes that become part of the production stream (e.g., by injection) and are co-produced from the well are included within the scope of the exemption (FR, 1993; EPA, 1995). Other wastes that may be generated in the oil field but are not intrinsic to oil production are not exempted, but subject to full regulation. The Federal exemption of E&P wastes from regulation as hazardous wastes under those conditions is commonly known as the E&P exemption.

The E&P exemption was also incorporated into California regulations, 22 CCR, Section 66261.4(b)(2) and 66261.24(a)(1), but it is limited in scope. The exemption applies in California in cases where the waste is hazardous solely by meeting the Federal characteristic for toxicity under the Toxicity Characteristic Leaching Procedure (TCLP). Thus, a waste that is hazardous solely by meeting or exceeding the maximum contaminant concentration for constituents extracted by TCLP, and for which Federal regulatory thresholds have been established, is exempted from regulation as hazardous waste in California. The exemption does not apply if toxicity is determined based on criteria other than TCLP, or the waste meets any of the other three characteristics of hazardous waste codified in 22 CCR, Article 3, Sections 66261.20 et seq., namely ignitability, corrosivity, and reactivity.

A “temporary” exemption was granted by Congress in 1980 and codified in Section 3001(b)(2)(A) of the Resource Conservation and Recovery Act (RCRA), pending a review of E&P wastes by the U.S. EPA (EPA, 1987). Upon completion of the review, U.S. EPA published a Regulatory Determination in the 1988 Federal Register, volume 53, page 25447, followed by a Clarification, which appeared in the 1993 Federal Register, volume 58, page 15284.

In the above mentioned publications, U.S. EPA stated that E&P wastes intrinsic to oil exploration and production should remain exempt from regulation as hazardous wastes under RCRA Subtitle C, and that regulation of E&P wastes should be carried out under less stringent RCRA Subtitle D standards. U.S. EPA also believed that proper management of E&P wastes might be achieved at the State level by improvement of existing State regulatory programs:

> “…In light of Congress’ concern for the protection of the nation’s future

> energy supply, Subtitle C regulations must be considered unwarranted. A tailored Subtitle D program, by contrast, will enable the Agency to apply all necessary requirements to the management of these wastes, while assuring that economic impacts are minimized" (FR, 1988, 25456);

and

> "The Agency believes that is impractical and inefficient to implement Subtitle C for all or some of these wastes because of the disruption and, in some cases, duplication of State authorities that administer programs through organizational structures tailored to the oil and gas industry". (FR, 1988, 25456)

U.S. EPA promised support to the States in enhancing existing programs for the management of E&P wastes:

> "Throughout the process of improving the Federal regulatory programs, EPA will work closely with States to encourage improvements in their regulatory programs". (FR, 1988, 25447)

Furthermore, U.S. EPA clarified that the E&P exemption did not imply that E&P wastes could not pose a hazard to public health and the environment, and acknowledged that regulation of certain E&P wastestreams as hazardous would be appropriate if the exemption were lifted:

> " It is clear that some portions of both the large-volume and associated waste would have to be treated as hazardous if the Subtitle C exemption were lifted" (FR, 1988, 25455).

The E&P exemption summarized above does not preclude the States from regulating E&P wastes. In general, E&P wastes that exhibit hazardous waste characteristics are subject to regulation as hazardous waste under the statutory authority of DTSC, except in those cases where the wastes are hazardous solely because they exhibit the Federal characteristic of toxicity.

Other agencies are involved in the regulation of E&P wastes as follows: the *California Department of Conservation* regulates the drilling, operation, maintenance, and plugging of oil, natural gas, and geothermal wells; the *Regional Water Quality Control Boards* regulate the discharge of wastes to land or surface waters; the *California Integrated Waste Management Board* regulates E&P wastes disposed in non-hazardous waste landfills; and the *California Air Resources Board* regulates emissions to air, including organic compound emissions from open pits and tanks. Within the scope and limitations of their specific programs, other State and Federal regulatory agencies, such as the *California Coastal Commission*, the *California Department of Fish and Game*, the *Minerals Management Service*, and the *Bureau of Land Management* may also be involved in the regulation of E&P wastes (IOGGC, 1993).

VI. PROJECT METHODOLOGY

1. Data quality objective

The primary data quality objective of the study was to collect and analyze samples that would be representative of the wastestream as a whole. To that end, SCD employed a sampling strategy based on scientific principles outlined in U.S. EPA's "Test Methods for Evaluating Solid Waste, Physical/Chemical Methods" publication SW-846, 3rd edition, 1996. Samples collected were adequate in terms of number and volume, field blanks were collected at a rate of 10% of the total number of waste samples collected, and all quality assurance procedures established for each test method were followed. Statistical analyses of the data were also completed and those findings are included with the discussion of results in this report.

2. Site selection criteria

E&P waste samples were collected at six oil production facilities in Los Angeles County and two oil production facilities in Kern County. Although the sampling sites were selected by SCD, participation in the study by each facility took place on a voluntary basis.

Sampling sites in Los Angeles County were of interest to DTSC due to their location in highly populated business or residential districts, and their proximity to public schools. Due to concerns regarding potential impacts of E&P wastes on children's health, DTSC selected for sampling facilities that produced oil (and therefore E&P wastes) within a quarter of a mile distance of a public school. Whenever possible, the sites were selected from different oil fields, to help diversify the sampling points.

In general, oil production facilities sampled in Los Angeles County were small-scale oil producers, occupying one or two blocks, and producing oil from older reservoirs by making use of waterflood, a type of enhanced recovery operation.

By contrast, facilities sampled in Kern County are representative of large-scale oil production. These facilities were selected based on their diversity of operation and availability of wastestreams of interest. General features included: extensive areas of operation in a rural-type setting, on-site recycling of certain types of wastes, and use of enhanced oil recovery by steam injection, a process known as steamflood.

3. Wastestreams sampled

Sampling efforts for this initiative were primarily focused on the wastestreams most prevalent in oil production, and therefore generated in the largest volumes. The inclusion of wastestreams in the study was limited by the waste's availability at the time of sampling. Smaller volume wastes associated with oil production were included, where available.

For the purpose of this discussion, the wastestreams sampled during this project have been categorized as produced water, drilling wastes, oily sludges, and foam treatment waste. Due to limited waste volume, only two samples were obtained of the latter wastestream. The sampling points for each wastestream varied depending on the location of the facility and methods of disposal used, as shown below:

- Produced water samples were taken from holding tanks intended for disposal into sewers, holding tanks for Class II injection wells, and from pipelines leading to an irrigation canal, intended for agricultural use;

- Drilling waste was sampled from earthen drilling pits, after the liquid phase of the waste had been aggregated with cement[1];

- Oily sludges were collected from covered and vented production pits, the bottom of water holding tanks (that waste is commonly referred to as "tank bottoms"), and from a pump cellar trough;

- Foam treatment waste was collected from the foam pumping equipment during a foam treatment operation in process.

A. Produced Water

Points of Generation

Produced water is the wastestream generated in the largest amounts by the oil production industry, at a ratio of 9:1 water to oil, according to information supplied by industry representatives. The total volume of produced water generated by oil production in California during 1995 is estimated to be approximately 1,684,200,000 barrels (API, 2000). Produced water is co-produced with crude oil and can be fresh or brackish, depending on the depth and composition of the formation. The constituents of produced water will also be determined by the characteristics of the formation, as water-soluble materials in the formation may be present in the water.

[1] The drilling waste therefore included cement as a component.

Produced water brought up to the surface is processed to remove the crude oil product. Treatment of produced water makes use of vessels such as free water knock-out tanks, heater-treater tanks, and water treatment plants. Prior to disposal, produced water is typically contained in large storage tanks.

Methods of Disposal

Methods of disposal encountered during the course of this study included discharge into sewer and percolation ponds under permits issued by the Regional Water Quality Control Boards (RWQCBs), injection into Class II disposal wells, and recycling for other uses. The practicality of the method depends largely on the regional characteristics. For example, percolation ponds would not be likely in an urban setting. Methods of disposal encountered in Los Angeles County were disposal into sewer and injection for enhanced recovery, or waterflood. In Kern County produced water was disposed into Class II disposal wells, percolation ponds, recycled for steam generation and injected into steamflood wells, and some produced water was used in agricultural irrigation canals. Table 1 lists data published by the American Petroleum Institute (API) on the volume and methods of disposal for produced water associated with oil production in California during 1995.

Table 1: Produced Water Generated by Oil Production in CA, 1995

Produced water in CA, 1995	Volume	Percentage
Reported volume produced water (1,000 barrels/year)	713,904	NA
Estimated volume of produced water (1,000 barrels/year)	1,684,200	NA
Injected for enhanced oil recovery (barrels/day)	365,844	51%
Injected for disposal onsite (barrels/day)	179,573	25%
Injected offsite (barrels/day)	5,050	0.7%
NA = Not Applicable		

Data source: API, 2000.

B. Drilling wastes

Points of Generation

Drilling for oil or natural gas resources generates drilling wastes. The estimated total volume of drilling wastes generated in California during 1995 was 1,826,401 barrels (API, 2000). These wastes consist mainly of formation materials displaced during drilling and coated with drilling fluid. Soil and rock cuttings are lifted to the surface by the fluid circulated through the drilling pipe and collected into a nearby earthen pit, called drilling pit (see Figures 4 and 5).

Figure 4: Drilling Pit Showing Drilling Waste

Figure 5: Drilling Waste Aggregated with Cement

The composition of the drilling wastes reflects the characteristics of the formation being drilled, and the composition of the drilling fluid utilized. Drilling waste often appears as sludge, with an aqueous layer floating on the surface. The composition of the drilling fluid itself might vary, depending on the circumstances of drilling. Typically a mixture of water and clay, drilling fluids may contain other additives. A common additive is barite, a weighting agent, used to improve the viscosity of the fluid and its ability to counterbalance the formation pressure and to float soil material to the surface. Oil-based and synthetic fluids are used in special circumstances, such as drilling to great depth or through high-pressure formations.

Note: The drilling waste sampled for this project consisted of drilling pit contents aggregated with cement. The drilling fluid used was water-based, with barite used as a weighting agent.

Methods of Disposal

Based on information supplied by industry representatives, the most common method of disposal for drilling wastes is on-site burial of drilling pit contents after aggregation of the aqueous component with cement. This method has regional limitations and may not be appropriate where drilling fluids other than water-based fluids are used. An alternate method of disposal is shipment to a commercial disposal facility that accepts E&P wastes. Table 2 lists available published data regarding the volume of drilling wastes and methods of disposal in California.

Table 2: Drilling Wastes in CA, 1995

Drilling wastes	**Barrels**	**Percentage**
Total estimated volume drilling wastes, solid and liquid	1,826,401.00	100%
Drilling waste produced with freshwater drilling fluid	1,789,872.98	98.0%
Drilling waste produced with oil-based drilling fluid	27,396.02	1.5%
Drilling waste produced with synthetic drilling fluid	9,132.01	0.5%
Estimated volume of liquid drilling waste disposed by method	**Barrels**	**Percentage**
Evaporate on or offsite	347,000.00	19.0%
Land spread onsite	804,000.00	44.0%
Land spread offsite	1,000.00	0.1%
Reuse for drilling	22,000.00	1.2%
Other	256,000.00	14.0%
Estimated volume of solid drilling waste disposed by method	**Barrels**	**Percentage**
Buried onsite	383,000.00	21.0%
Land spread onsite	5,000.00	0.3%
Land spread offsite	2,000.00	0.1%
Commercial disposal facility	4,000.00	0.2%
Industrial or municipal landfill	2,000.00	0.1%
Other	401.00	0.02%

Data source: API, 2000

C. Oily sludges

Points of Generation

Sludge waste generally consists of oily sands and untreatable emulsions segregated from the production stream, and sediment accumulated on the bottom of crude oil and water storage tanks. The estimated total volume of oily sludge generated in California during 1995 was 220,300 barrels (API, 2000). Sludge samples during this project were collected from production pits and from the bottom of water holding tanks. Table 3 displays API's estimation of the number of production pits and tanks associated with production facilities in

California as of 1995.

Methods of Disposal

In an urban setting a common method of disposal for oily sludges is shipment to a commercial facility that accepts E&P waste. According to industry representatives, in a rural setting tank bottoms and other sludges are often recycled and used for fabrication of road mix. The sludge material is processed at an on-site roadmap facility, and the resulting material is applied to private roads within the facility, due to its dust-suppressing properties.

Table 3: Production Facilities in California, 1995

Estimated number of oil production facilities	8,610
Estimated number of production pits	234
Estimated number of tanks associated with production facilities	34,440

Data source: API, 2000

D. Foam treatment waste

Points of Generation

A foam treatment operation is a workover procedure whereby soap is injected into a well to dissolve paraffin deposits that hinder production. This is an inexpensive alternative to acidizing, or the injection of strong acid for removal of salt scale or paraffin. Fluids injected to remove unwanted deposits and circulated back up to the surface are usually referred to as stimulation fluids.

Stimulation fluids are workover wastes which are grouped in the category of associated wastes. Although most types of associated wastes were not sampled due to unavailability during this study, published data pertaining to associated wastes are included for reference in Table 4.

Table 4: Associated Wastes in CA, 1995

Associated Waste Volume (barrels/year)	**Reported**	**Estimated**
Reported volume completion fluids (from well completions)	262,300	431,300
Reported volume stimulation fluids (from well workovers)	155,020	945,600
Associated waste disposal by method (barrels/year)	**Reported**	**Percentage**
Disposal by injection	7,060	1.5%
Land spread within field	12,400	3%
Land spread outside field	4,500	1%
Road spread within field	7,300	2%
Crude oil reclamation	3,000	0.7%
Recycled and reused	221,000	48.3%
Commercial disposal facility	800	0.2%
Incinerated	2	Not known

Data source: API, 2000

Note: wastes generated by the production of natural gas are not addressed within the scope of this report. Natural gas and hydrogen sulfide gas are often co-produced with the oil. Natural gas is isolated early on in production and marketed as a separate product. Hydrogen sulfide gas is also present in certain formations: it constitutes a waste and is flared or injected into Class II disposal wells alongside other waste fluids.

To summarize, the wastestreams sampled during this project were produced water, drilling waste, oily sludges, and workover waste from a foam treatment operation. Table 5 summarizes the wastestreams sampled, their points of generation, and methods of disposal encountered at each facility. The names of the facilities are kept confidential by giving the sites a number 1 through 8 designation.

Table 5: Wastestreams Sampled and Methods of Disposal at Participating Facilities

Facility No.	City and County in CA	Oil Field	Wastestream sampled	Sampling point	Method of disposal[2]
No.1	Los Angeles, Los Angeles	Los Angeles City	1. Produced water	Produced water holding tank	Sewer, per RWQCB permit
			2. Oily sludge	Water tank bottom	Shipped offsite to commercial E&P disposal facility
No. 2	Los Angeles, Los Angeles	Torrance	1. Produced water	Produced water holding tank	Sewer, per RWQCB permit
			2. Oily sludge	Vented production pit	Shipped offsite to commercial E&P disposal facility
No. 3	Beverly Hills, Los Angles	Beverly Hills	1. Produced water	Produced water holding tank	Re-injected for enhanced oil recovery (waterflood)
			2. Oily sludge	Pump cellar trough	Shipped offsite to commercial E&P disposal facility
No. 4	Harbor City, Los Angeles	Potrero	1. Produced water	Produced water holding tank	Re-injected for enhanced oil recovery (waterflood)
			2. Oily sludge	Covered production pit	Shipped offsite to commercial E&P disposal facility
			3. Oily sludge	Water tank bottom	Shipped offsite to commercial E&P disposal facility
No. 5	Wilmington, Los Angeles	Wilmington	1. Produced water	Produced water holding tank	Re-injected for enhanced oil recovery (waterflood)
			2. Oily sludge	Production pit	Shipped offsite to commercial E&P disposal facility
			3. Oily sludge	Water tank bottom	Shipped offsite to commercial E&P disposal facility
No. 6	Wilmington, Los Angeles	Wilmington	1. Produced water	Produced water holding tank	Re-injected for enhanced oil recovery (waterflood)
			2. Oily sludge	Production pit	Shipped offsite to commercial E&P disposal facility
No. 7	Bakersfield, Kern	Kern River	1. Produced water	Water holding tank	Discharged into Cawelo Water District canal
			2. Produced water	Injection well storage tank	Injected into Class II disposal well
			3. Oily sludge	Injection well tank bottom	Recycled at road mix facility, onsite
			4. Drilling waste	Drilling pit	Aggregated with cement and buried on location or shipped offsite to commercial E&P disposal facility
No. 7	Bakersfield, Kern	Kern River	5. Oily sludge	Water tank bottom	Recycled at roadmix facility
			6. Foam treatment waste	Pumping equipment that circulates the waste to the surface	Injected into Class II disposal well
No. 8	Bakersfield, Kern	Kern River	1. Produced water	Produced water holding tank	Discharged into canal to be used for agricultural irrigation
			2. Drilling waste	Drilling pit	Aggregated with cement and buried on location or shipped offsite to commercial E&P disposal facility

[2] According to information supplied by facility representatives.

VII. ANALYSES PERFORMED AND DATA OBTAINED

The E&P waste samples collected were analyzed under the following parameters of study: pH; flash point; aquatic toxicity; metals; volatile organic compounds (VOCs); semi-volatile organic compounds (SVOCs); benzene; toluene; xylene (BTX); and total petroleum hydrocarbons (TPH).

The number of samples analyzed was not the same for all tests. For example, the aquatic toxicity bioassay was conducted on one sample per wastestream, per facility. The number of sampled analyzed for VOCs and SVOCs was also smaller due to financial limitations, but was sufficient to support interpretive conclusions.

Table 6 is a complete listing of all parameters of analysis, the number of samples analyzed for each wastestream, parameters of study, and number and percentages of samples with values below detection limits, where detection limits are applicable. Because each wastestream displayed variation in the type of analytes detected, subsequent tables list only detected analytes for the wastestreams presented.

Tables 7, 9, 11, and 13 summarize results obtained for produced water, drilling waste, oily sludge, and foam treatment waste, respectively. The statistical calculations included for each parameter are mean, median, standard deviation, and percentages of samples with values above the regulatory threshold (RT), where RTs are applicable. The following approach was used for statistical calculations involving the data.

For some tests (e.g., VOCs), the values obtained were below detection limits, or not detected (ND). According to standard DTSC procedure, for purposes of statistical calculations ND values are typically replaced with half the value of the detection limit (DL). This procedure assumes that if a contaminant was not detected, it is present in the sample at a concentration that is equal to half the lowest detectable concentration. Given the fact that DL is not a constant for each test but varies with the matrix for each individual sample, SCD chose to forgo the above procedure for practical reasons, and assume a value of 0 for all ND values. This method theoretically introduces a bias in the data in favor of the generator, by assuming that if a contaminant was not detected, is was not present in the sample in any concentration. However, for purposes of this project, it was determined that using 0 in lieu of half DL in statistical calculations would not affect the outcome of the study, because the concentration of the detected analytes in those samples was far below RT.

It was noted that the data obtained from some analyses did not display a normal distribution, as indicated by the fact that the mean value was lower than the standard deviation value. Possible factors causing the large variation in the sample population are summarized in the Discussion of Results section of this report. In order to normalize the data for purposes of calculating the upper confidence interval limit (UCL) for a normally distributed population, the data were transformed using the arcsine transformation.[3] Where applicable, the UCL was calculated using an 80% confidence interval for a normally distributed population. The data transformation was only carried out for tests with established RT values, as the calculation of the UCL is only relevant when compared to RT, for the purpose of determining if the waste is hazardous. The relationship between UCL and RT can be evaluated as follows: as UCL approaches RT, the waste tends to be hazardous. If UCL is lower than RT, it is concluded that the waste is not hazardous. Tables 8, 10, 12, and 14 list statistical calculations for transformed data for tests with established RT values.

Note: E&P wastes, particularly produced water or scale deposited on downhole equipment, may also contain Naturally Occurring Radioactive Materials (NORM) (DHS et al, 1996). Analyzing collected samples for NORM was beyond the scope of this project. Radiation detection equipment was utilized during sampling to ensure freedom from radioactive exposure of the sampling team.

[3] A mathematical procedure which converts both the data points and the regulatory threshold values into proportions, followed by the calculation of the square root and of the arcsine value.

Table 6: Parameters, Total Number of Samples Analyzed for Each Wastestream, and Total Number of Samples below Detection Limits

	TOTAL NUMBER OF SAMPLES ANALYZED				NUMBER OF SAMPLES BELOW DETECTION LIMITS (ND)							
PARAMETER	**Prod. Water**	**Oily sludge**	**Drilling waste**	**Foam treatment waste**	**Prod. Water**	**% Prod. Water**	**Oily Sludge**	**% Oily Sludge**	**Drilling Waste**	**% Drilling Waste**	**Foam Treatment Waste**	**% Foam Treatment Waste**
pH	36	35	8	2	N/A							
Flash point (degrees Fahrenheit)	36	34	8	2	N/A							
Total Sulfides mg/l (l), mg/kg (s) [4]	36	35	8	2	36	100%	17	49%	1	13%	2	100%
Aquatic Toxicity Bioassay (mg/l)	9	14	2	1	N/A							
TPH mg/l (l); mg/kg (s)	36	30	8	2	13	36%	0	0%	0	0%	0	0%
Metals												
Silver	36	35	8	2	36	100%	31	89%	8	100%	2	100%
Arsenic	36	35	8	2	36	100%	34	97%	8	100%	2	100%
Barium	36	35	8	2	11	31%	7	20%	0	0%	0	0%
Beryllium	36	35	8	2	36	100%	24	69%	8	100%	2	100%
Cadmium	36	35	8	2	32	89%	35	100%	8	100%	2	100%
Cobalt	36	35	8	2	36	100%	29	83%	8	100%	2	100%
Chromium	36	35	8	2	34	94%	22	63%	8	100%	2	100%
Copper	36	35	8	2	33	92%	12	34%	8	100%	0	0%
Molybdenum	36	35	8	2	36	100%	34	97%	8	100%	2	100%
Nickel	36	35	8	2	36	100%	14	40%	7	88%	2	100%
Lead	36	35	8	2	36	100%	27	77%	8	100%	0	0%
Antimony	36	35	8	2	36	100%	35	100%	8	100%	2	100%
Selenium	36	35	8	2	36	100%	32	91%	8	100%	0	0%
Thallium	36	35	8	2	35	97%	32	91%	8	100%	2	100%

[4] (l) indicates liquid waste, such as produced water or foam treatment waste; (s) indicates solid or semi-solid waste, such as sludge.

	TOTAL NUMBER OF SAMPLES ANALYZED				NUMBER OF SAMPLES BELOW DETECTION LIMITS (ND)							
PARAMETER	Prod. Water	Oily sludge	Drilling waste	Foam treatment waste	Prod. Water	% Prod. Water	Oily Sludge	% Oily Sludge	Drilling Waste	% Drilling Waste	Foam Treatment Waste	% Foam Treatment Waste
Vanadium	36	35	8	2	36	100%	24	69%	8	100%	2	100%
Zinc	36	35	8	2	30	83%	12	34%	8	100%	0	0%
BTX ug/L (l); mg/kg (s)												
Benzene	35	26	8	2	4	11%	8	31%	8	100%	2	100%
Ethyl benzene	35	26	8	2	12	34%	10	38%	8	100%	2	100%
Methyl t-butyl ether	31	25	8	2	27	87%	21	84%	8	100%	2	100%
Toluene	35	26	8	2	4	11%	6	23%	8	100%	2	100%
Xylene (total)	35	26	8	2	1	3%	1	4%	4	50%	2	100%
Volatile Organics ug/l (l);mg/kg (s)												
Freon-12	32	30	8	2	32	100%	29	97%	8	100%	2	100%
Chloromethane	32	30	8	2	32	100%	30	100%	8	100%	2	100%
Vinyl Chloride	32	30	8	2	32	100%	30	100%	8	100%	2	100%
Methyl Bromide	32	30	8	2	32	100%	30	100%	8	100%	2	100%
Chloroethane	32	30	8	2	32	100%	30	100%	8	100%	2	100%
Freon-11	32	30	8	2	32	100%	29	97%	8	100%	2	100%
Acetone	28	30	8	2	8	29%	28	93%	8	100%	2	100%
1,1-Dichloroethene	32	30	8	2	32	100%	30	100%	8	100%	2	100%
Methylene Chloride	32	30	7	2	32	100%	30	100%	7	100%	2	100%
trans-1,2-Dichloroethene	32	30	8	2	32	100%	30	100%	8	100%	2	100%
1,1-Dichloroethane	32	30	8	2	32	100%	30	100%	8	100%	2	100%
2-Butanone	32	30	8	2	16	50%	29	97%	8	100%	2	100%
cis-1,2-dichloroethene	32	30	8	2	32	100%	30	100%	8	100%	2	100%
2,2-Dichloropropane	32	30	8	2	32	100%	30	100%	8	100%	2	100%
Chloroform	32	30	8	2	28	88%	30	100%	8	100%	2	100%
Bromochloromethane	32	30	8	2	28	88%	26	87%	8	100%	2	100%
1,1,1-Trichloroethane	32	30	8	2	32	100%	30	100%	8	100%	2	100%

	TOTAL NUMBER OF SAMPLES ANALYZED				NUMBER OF SAMPLES BELOW DETECTION LIMITS (ND)							
PARAMETER	Prod. Water	Oily sludge	Drilling waste	Foam treatment waste	Prod. Water	% Prod. Water	Oily Sludge	% Oily Sludge	Drilling Waste	% Drilling Waste	Foam Treatment Waste	% Foam Treatment Waste
1,2 Dichloroethane	32	30	8	2	32	100%	30	100%	8	100%	2	100%
Benzene	32	30	8	2	11	34%	16	53%	8	100%	2	100%
1,1-Dichloropropene	32	30	8	2	30	94%	30	100%	8	100%	2	100%
Carbontetrachloride	32	30	8	2	32	100%	30	100%	8	100%	2	100%
1,2-Dichloropropane	32	30	8	2	32	100%	30	100%	8	100%	2	100%
Trichloroethene	32	30	8	2	32	100%	30	100%	8	100%	2	100%
Dibromomethane	32	30	8	2	32	100%	30	100%	8	100%	2	100%
Bromodichloromethane	32	30	8	2	28	88%	30	100%	8	100%	2	100%
4-Methyl-2-Pentanone	32	30	8	2	32	100%	30	100%	8	100%	2	100%
1,1,2-Trichloroethane	32	30	8	2	32	100%	30	100%	8	100%	2	100%
Toluene	32	30	8	2	20	63%	15	50%	8	100%	2	100%
2-Hexanone	32	30	8	2	32	100%	30	100%	8	100%	2	100%
1,3-Dichloropropane	32	30	8	2	32	100%	30	100%	8	100%	2	100%
Dibromochloromethane	32	30	8	2	32	100%	30	100%	8	100%	2	100%
1,2-Dibromoethane	32	30	8	2	32	100%	30	100%	8	100%	2	100%
Tetrachloroethene	32	30	8	2	32	100%	30	100%	8	100%	2	100%
Chlorobenzene	32	30	8	2	32	100%	30	100%	8	100%	2	100%
1,1,1,2-Tetrachloroethane	32	30	8	2	32	100%	29	97%	8	100%	2	100%
Ethyl benzene (ug/l)	32	30	8	2	24	75%	13	43%	8	100%	2	100%
M&P-Xylenes	32	30	8	2	20	63%	9	30%	7	88%	2	100%
Bromoform	32	30	8	2	32	100%	30	100%	8	100%	2	100%
Styrene	32	30	8	2	32	100%	30	100%	8	100%	2	100%
O-Xylene	32	30	8	2	10	31%	6	20%	8	100%	2	100%
1,1,2,2-Tetrachloroethane	32	30	8	2	32	100%	30	100%	8	100%	2	100%
1,2,3-Trichloropropane	32	30	8	2	32	100%	30	100%	8	100%	2	100%
Isopropylbenzene	32	30	8	2	32	100%	23	77%	8	100%	2	100%

	TOTAL NUMBER OF SAMPLES ANALYZED				NUMBER OF SAMPLES BELOW DETECTION LIMITS (ND)							
PARAMETER	Prod. Water	Oily sludge	Drilling waste	Foam treatment waste	Prod. Water	% Prod. Water	Oily Sludge	% Oily Sludge	Drilling Waste	% Drilling Waste	Foam Treatment Waste	% Foam Treatment Waste
Bromobenzene	32	30	8	2	32	100%	30	100%	8	100%	2	100%
2-Chlorotoluene	32	30	8	2	32	100%	30	100%	8	100%	2	100%
N-Propylbenzene	32	30	8	2	32	100%	18	60%	8	100%	2	100%
4-Chlorotoluene	32	30	8	2	32	100%	30	100%	8	100%	2	100%
1,3,5-Trimethylbenzene	32	30	8	2	20	63%	9	30%	8	100%	2	100%
tert-Butylbenzene	32	30	8	2	32	100%	30	100%	8	100%	2	100%
1,2,4-Trimethylbenzene	32	30	8	2	14	44%	11	37%	8	100%	2	100%
1,3-Dichlorobenzene	32	30	8	2	32	100%	30	100%	8	100%	2	100%
Sec-Butylbenzene	32	30	8	2	32	100%	22	73%	8	100%	2	100%
1,4-Dichlorobenzene	32	30	8	2	32	100%	30	100%	8	100%	2	100%
P-Isopropyltoluene	32	30	8	2	32	100%	30	100%	8	100%	2	100%
1,2-Dichlorobenzene	32	30	8	2	32	100%	30	100%	8	100%	2	100%
N-Butylbenzene	32	30	8	2	32	100%	30	100%	8	100%	2	100%
1,2,4-Trichlorobenzene	32	30	8	2	32	100%	30	100%	8	100%	2	100%
Naphthalene	32	30	8	2	24	75%	16	53%	8	100%	2	100%
1,2,3-Trichlorobenzene	32	30	8	2	32	100%	30	100%	8	100%	2	100%
Hexachlorobutadiene	32	30	8	2	32	100%	29	97%	8	100%	2	100%
Semi-Volatile Organics ug/l (l);mg/kg (s)												
1,3 Dichlorobenzene	32	36	8	2	32	100%	32	89%	8	100%	2	100%
Bis(2-Chloroethyl)Ether	32	36	8	2	32	100%	36	100%	8	100%	2	100%
1,4-Dichlorobenzene	32	36	8	2	32	100%	36	100%	8	100%	2	100%
1,2-Dichlorobenzene	32	36	8	2	32	100%	36	100%	8	100%	2	100%
Hexachloroethane	32	36	8	2	32	100%	36	100%	8	100%	2	100%
Bis(2-Chloroisopropyl)Ether	32	36	8	2	32	100%	36	100%	8	100%	2	100%
N-Nitroso-Di-N-Propylamine	32	36	8	2	32	100%	36	100%	8	100%	2	100%
Nitrobenzene	32	36	8	2	32	100%	36	100%	8	100%	2	100%

	TOTAL NUMBER OF SAMPLES ANALYZED				NUMBER OF SAMPLES BELOW DETECTION LIMITS (ND)							
PARAMETER	**Prod. Water**	**Oily sludge**	**Drilling waste**	**Foam treatment waste**	**Prod. Water**	**% Prod. Water**	**Oily Sludge**	**% Oily Sludge**	**Drilling Waste**	**% Drilling Waste**	**Foam Treatment Waste**	**% Foam Treatment Waste**
Isophorone	32	36	8	2	32	100%	36	100%	8	100%	2	100%
1,2,4-Trichlorobenzene	32	36	8	2	32	100%	36	100%	8	100%	2	100%
Bis(2-Chloroethoxy)methane	32	36	8	2	32	100%	36	100%	8	100%	2	100%
Hexachlorobutadiene	32	36	8	2	32	100%	36	100%	8	100%	2	100%
Hexachlorocyclopentadiene	32	36	8	2	32	100%	36	100%	8	100%	2	100%
2-Chloronaphthalene	32	36	8	2	32	100%	36	100%	8	100%	2	100%
Dimethylphthalate	32	36	8	2	32	100%	36	100%	8	100%	2	100%
2,6,-Dinitrotoluene	32	36	8	2	32	100%	36	100%	8	100%	2	100%
4-Chlorophenyl Phenyl Ether	32	36	8	2	32	100%	36	100%	8	100%	2	100%
2,4-Dinitrotoluene	32	36	8	2	32	100%	36	100%	8	100%	2	100%
Diethyl Phthalate	32	36	8	2	32	100%	36	100%	8	100%	2	100%
N-Nitrosodiphenylamine	32	36	8	2	32	100%	36	100%	8	100%	2	100%
4-Bromophenyl Phenyl Ether	32	36	8	2	32	100%	36	100%	8	100%	2	100%
Hexachlorobenzene	32	36	8	2	32	100%	36	100%	8	100%	2	100%
Di-n-Butyl Phthalate	32	36	8	2	32	100%	36	100%	8	100%	2	100%
Butyl Benzyl Phthalate	32	36	8	2	32	100%	36	100%	8	100%	2	100%
Bis(2-Ethyl Hexyl)Phthalate	32	36	8	2	32	100%	36	100%	8	100%	2	100%
3,3-Dichlorobenzidine	32	36	8	2	32	100%	36	100%	8	100%	2	100%
Di-n-Octyl Phthalate	32	36	8	2	32	100%	35	97%	8	100%	2	100%
Naphthalene	32	36	8	2	32	100%	23	64%	8	100%	2	100%
Acenaphthalene	32	36	8	2	32	100%	36	100%	8	100%	2	100%
Acenaphthene	32	36	8	2	32	100%	36	100%	8	100%	2	100%
Fluorene	32	36	8	2	32	100%	33	92%	8	100%	2	100%
Phenanthrene	32	36	8	2	32	100%	27	75%	8	100%	2	100%

	TOTAL NUMBER OF SAMPLES ANALYZED				NUMBER OF SAMPLES BELOW DETECTION LIMITS (ND)							
PARAMETER	**Prod. Water**	**Oily sludge**	**Drilling waste**	**Foam treatment waste**	**Prod. Water**	**% Prod. Water**	**Oily Sludge**	**% Oily Sludge**	**Drilling Waste**	**% Drilling Waste**	**Foam Treatment Waste**	**% Foam Treatment Waste**
Anthracene	32	36	8	2	32	100%	32	89%	8	100%	2	100%
Fluoranthene	32	36	8	2	32	100%	36	100%	8	100%	2	100%
Pyrene	32	36	8	2	32	100%	36	100%	8	100%	2	100%
Benzo[a]Anthracene	32	36	8	2	32	100%	36	100%	8	100%	2	100%
Chrysene	32	36	8	2	32	100%	36	100%	8	100%	2	100%
Benzo[b]Fluoranthene	32	36	8	2	32	100%	36	100%	8	100%	2	100%
Benzo[k]Fluoranthene	32	36	8	2	32	100%	36	100%	8	100%	2	100%
Benzo[a]Pyrene	32	36	8	2	32	100%	36	100%	8	100%	2	100%
Ideno[1, 2,3-c,d]Pyrene	32	36	8	2	32	100%	36	100%	8	100%	2	100%
Dibenz[a,h]Anthracene	32	36	8	2	32	100%	36	100%	8	100%	2	100%
Benzo[g,h,i]Perylene	32	36	8	2	32	100%	36	100%	8	100%	2	100%
2-Chlorophenol	32	36	8	2	32	100%	36	100%	8	100%	2	100%
Phenol	32	36	8	2	32	100%	36	100%	8	100%	2	100%
2-Nitrophenol	32	36	8	2	32	100%	36	100%	8	100%	2	100%
2,4-Dimethyl Phenol	32	36	8	2	32	100%	36	100%	8	100%	2	100%
2,4-Dichlorophenol	32	36	8	2	32	100%	36	100%	8	100%	2	100%
4-Chloro-3-Methyl Phenol	32	36	8	2	32	100%	36	100%	8	100%	2	100%
2,4,6-Trichlorophenol	32	36	8	2	32	100%	36	100%	8	100%	2	100%
2,4-Dinitrophenol	32	36	8	2	32	100%	36	100%	8	100%	2	100%
2-Methyl-4,6-Dinitrophenol	32	36	8	2	32	100%	36	100%	8	100%	2	100%
4-Nitro Phenol	32	36	8	2	32	100%	36	100%	8	100%	2	100%
Pentachlorophenol	32	36	8	2	32	100%	36	100%	8	100%	2	100%
Benzyl Alcohol	32	36	8	2	32	100%	36	100%	8	100%	2	100%
2-Methylphenol	32	36	8	2	32	100%	36	100%	8	100%	2	100%
4 and/or 3-Methylphenol	32	36	8	2	32	100%	36	100%	8	100%	2	100%
Carbazole	32	36	8	2	32	100%	36	100%	8	100%	2	100%

	TOTAL NUMBER OF SAMPLES ANALYZED				NUMBER OF SAMPLES BELOW DETECTION LIMITS (ND)							
PARAMETER	Prod. Water	Oily sludge	Drilling waste	Foam treatment waste	Prod. Water	% Prod. Water	Oily Sludge	% Oily Sludge	Drilling Waste	% Drilling Waste	Foam Treatment Waste	% Foam Treatment Waste
4-Chloroaniline	32	36	8	2	32	100%	36	100%	8	100%	2	100%
2-Methyl Naphthalene	32	36	8	2	32	100%	16	44%	8	100%	2	100%
2,4,5-Trichlorophenol	32	36	8	2	32	100%	36	100%	8	100%	2	100%
2-Nitroaniline	32	36	8	2	32	100%	36	100%	8	100%	2	100%
Dibenzofuran	32	36	8	2	32	100%	36	100%	8	100%	2	100%
3-Nitroaniline	32	36	8	2	32	100%	36	100%	8	100%	2	100%
4-Nitroaniline	32	36	8	2	32	100%	36	100%	8	100%	2	100%
Aniline	32	36	8	2	32	100%	36	100%	8	100%	2	100%

Prod. water = produced water; N/A = not applicable.

Table 7: Detected Analytes in Produced Water

PARAMETER	Regulatory Threshold	n	Total ND	% ND	Range	Median	Mean	SD	% above RT
pH	2 or lower; 12.5 or higher	36	0	0%	7.18-9.63	7.8	7.8	0.5	0%
Flash point (degrees Fahrenheit)[5]	<140 degrees Fahrenheit	36	0	0%	>140	NA	NA	NA	0%
Total Sulfides (mg/l)	500 mg/kg, reactive sulfides	36	36	100%	NA	NA	NA	NA	0%
Aquatic Toxicity (mg/l)	less than 500 mg/l	9	0	0%	587-697	624.0	NA	NA	0%
TPH mg/l	NA	36	13	36%	ND-530	16.0	75.0	147.5	NA
Metals, STLC (mg/l)									
Barium	STLC 100 (mg/l)	36	11	31%	ND-39	28.0	16.6	15.8	0%
Cadmium	STLC 1.0 (mg/l)	36	32	89%	ND-0.05	0.1	0.0	0.0	0%
Chromium	STLC 5 (mg/l)	36	34	94%	ND-1.1	1.1	0.0	0.2	0%
Thallium	STLC 7.0 (mg/l)	36	35	97%	ND-2.4	2.4	0.1	0.4	0%
Zinc	STLC 250 (mg/l)	36	30	83%	ND-27	2.6	1.6	5.7	0%
BTX (ug/l)									
Benzene	NA	35	4	11%	ND-3930	60.0	712.7	1,192.4	NA
Ethyl benzene	NA	35	12	34%	ND-255	30.0	59.0	89.5	NA
Methyl t-butyl ether	NA	31	27	87%	ND-285	143.5	34.5	80.9	NA
Toluene	NA	35	4	11%	ND-2,260	22.0	438.0	728.9	NA
Xylene (total)	NA	35	1	3%	ND-1,330	191.5	310.5	407.9	NA
Volatile Organics (ug/l)									
Acetone	NA	28	8	29%	ND-12,000	160.0	501.1	1,965.2	NA
2-Butanone	NA	32	16	50%	ND-320	15.5	38.0	94.7	NA
Chloroform	TCLP 6.0 mg/l (6,000 ug/l)	32	28	88%	ND-2.8	2.7	0.3	0.8	NA
Bromochloromethane	NA	32	28	88%	ND-1	0.9	0.1	0.3	NA
Benzene	TCLP 0.5 mg/l (500 ug/l)	32	11	34%	ND-2,100	1.7	268.3	607.5	NA[6]
1,1-Dichloropropene	NA	32	30	94%	ND-34	30.5	1.7	7.0	NA
Bromodichloromethane	NA	32	28	88%	ND-1.1	1.0	0.1	0.3	NA

[5] The sludge waste contained sufficient liquid content to allow the flash point test to be performed.
[6] E&P exemption applies.

PARAMETER	Regulatory Threshold	n	Total ND	% ND	Range	Median	Mean	SD	% above RT
Toluene	NA	32	20	63%	ND-1,600	460.0	220.3	484.6	NA
Ethyl benzene	NA	32	24	75%	ND-120	63.5	15.7	36.0	NA
m&p-Xylenes	NA	32	20	63%	ND-600	155.0	79.8	178.1	NA
o-Xylene	NA	32	10	31%	ND-250	58.5	43.0	75.4	NA
1,3,5-Trimethylbenzene	NA	32	20	63%	ND-94	6.1	9.8	25.7	NA
1,2,4-Trimethylbenzene	NA	32	14	44%	ND-210	29.5	34.2	60.8	NA
Naphthalene	NA	32	24	75%	ND-66	44.5	10.0	20.8	NA

Table 8: Statistical Analysis of Transformed Data for Produced Water (tests with RT values only)

PARAMETER	Mean	Standard Deviation	Upper Confidence Interval Limit (UCL)	Regulatory Threshold	UCL compared to RT
pH	7.80	0.01	7.90	2 or lower; 12.5 or higher	UCL<RT
Barium	11.83 mg/l	5.23	15.43 mg/l	STLC: 100 mg/l	UCL<RT
Cadmium	0.08 mg/l	0.00	0.09 mg/l	STLC: 1.0 mg/l	UCL<RT
Chromium	0.21 mg/l	0.17	0.30 mg/l	STLC: 5.0 mg/l	UCL<RT
Thallium	0.33 mg/l	0.28	0.47 mg/l	STLC: 7.0 mg/l	UCL<RT
Zinc	0.75 mg/l	1.25	1.23 mg/l	STLC: 250 mg/l	UCL<RT
Chloroform	0.03 ug/l	0.27	0.09 ug/l	TCLP: 6.0 mg/l (6,000 ug/l)	UCL<RT
Benzene	64.30 ug/l	224.88	125.86 ug/l	TCLP: 0.5 mg/l (500 ug/l)	UCL<RT

Table 9: Detected Analytes in Drilling Waste

PARAMETER	Regulatory Threshold	n	Tot. ND	% ND	Range	Median	Mean	SD	% above RT
pH	2 or lower; 12.5 or higher	8	0	0%	8.7-11.96	11.52	10.7	1.4	0%
Flash point (degrees Fahrenheit)	<140 degrees Fahrenheit	8	0	0%	>140	NA	NA	NA	NA
Total Sulfides (mg/kg)	500 mg/kg, reactive sulfides	8	1	13%	ND-40	28.00	25.0	11.1	0%
Aquatic Toxicity (mg/l)	less than 500 mg/l	2	0	0%	680-680	680.00	NA	NA	NA
TPH (mg/kg)	NA	8	0	0%	100.0-2,500.0	375.00	588.8	738.7	NA
Metals (TTLC: mg/kg)									
Barium	TTLC 10,000	8	0	0%	57.0-200.0	75.50	94.9	44.6	0%
Nickel	TTLC 2,000	8	7	88%	ND-56.0	56.00	7.0	18.5	0%
BTX (mg/kg)									0%
Xylene (total)	NA	8	4	50%	ND-0.37	0.20	0.1	0.1	NA
Volatile Organics (mg/kg)									
Methylene Chloride	NA	8	7	88%	ND-1.4	1.40	0.2	0.5	NA
M&P-Xylenes	NA	8	7	88%	ND-100.0	100.00	12.5	33.1	NA

Table 10: Statistical Analysis of Transformed Data for Drilling Waste (tests with RT values only)

PARAMETER	Mean	Standard Deviation	Upper Confidence Interval Limit	Regulatory Threshold	UCL compared to RT
pH	10.64	0.05	11.40	2 or lower, 12.5 or higher	UCL<RT
Total Sulfides	21.63 mg/kg	3.86	31.73 mg/kg	500 mg/kg	UCL<RT
Barium	90.78 mg/kg	4.79	112.72 mg/kg	TTLC: 10,000 mg/kg	UCL<RT
Nickel	50.73 mg/kg	0.02	51.78 mg/kg	TTLC: 2,000 mg/kg	UCL<RT

Table 11: Detected Analytes in Oily Sludge

PARAMETER	Regulatory Threshold	n	Tot ND	% ND	Range	Median	Mean	SD	% above RT
pH	2 or lower; 12.5 or higher	35	0	0%	7.1-8.95	7.6	7.7	0.5	0%
Flash point (degrees Fahrenheit)	<140 degrees Fahrenheit	34	0	0%	<65 -140	NA	NA	NA	11%
Total Sulfides (mg/kg)	500 mg/kg, reactive sulfides	35	17	49%	ND-688	270.0	158.4	195.7	0%
Aquatic Toxicity (mg/l)	less than 500 mg/l	14	0	0%	750-750	750.0	21.4	124.9	0%
TPH (mg/kg)		30	0	0%	3,500-160,000	28,000.0	38,366.6	40,792.3	0%
Metals (TTLC: mg/kg)									
Arsenic	TTLC 500	35	34	97%	ND-5.1	5.1	0.2	0.9	0%
Barium	TTLC 10,000	35	7	20%	ND-4600	117.0	848.7	1,204.3	0%
Beryllium	TTLC 75	35	24	69%	ND-0.43	0.3	0.1	0.1	0%
Cobalt	TTLC 8,000	35	29	83%	ND-6.7	4.9	0.7	1.8	0%
Chromium	TTLC 2,500	35	22	63%	ND-99	54.0	19.1	31.2	0%
Copper	TTLC 2,500	35	12	34%	ND-560	70.0	73.1	137.7	0%
Molybdenum	TTLC 3,500	35	34	97%	ND-10.5	10.5	0.3	1.8	0%
Nickel	TTLC 2,000	35	14	40%	ND-116	55.3	29.8	32.7	0%
Lead	TTLC 1,000	35	27	77%	ND-2,200	823.7	227.8	615.5	0%
Selenium	TTLC 100	35	32	91%	ND-13	13.0	0.8	3.1	0%
Vanadium	TTLC 2,400	35	24	69%	ND-57.2	30.7	11.6	18.6	0%
Zinc	TTLC 5,000	35	12	34%	ND-3,200	125.5	329.0	655.5	0%
BTX (mg/kg)									
Benzene	NA	26	8	31%	ND-1,040	8.1	90.2	244.8	0%
Ethyl benzene	NA	26	10	38%	ND-1,180	73.0	125.0	297.2	0%
Methyl t-butyl ether	NA	25	21	84%	ND-86	86.0	2.5	14.3	0%
Toluene	NA	26	6	23%	ND-3,770	10.1	324.5	932.1	0%
Xylene (total)	NA	26	1	4%	ND-6,490	52.0	658.5	1,650.9	0%
Volatile Organics (mg/kg)									
Freon-11	NA	30	29	97%	ND-230	230.0	6.6	38.3	0%
Acetone	NA	30	28	93%	ND-120	115.0	6.6	26.7	0%
2-Butanone	NA	30	29	97%	ND-58	58.0	1.7	9.7	0%
Benzene	NA	30	16	53%	ND-7,000	45.0	264.4	1,170.6	0%

PARAMETER	Regulatory Threshold	n	Tot ND	% ND	Range	Median	Mean	SD	% above RT
Toluene	NA	30	15	50%	ND-8,700	22.0	405.4	1,494.7	0%
1,1,1,2-Tetrachloroethane	NA	30	29	97%	ND-10	10.0	0.3	1.7	0%
Ethyl benzene (ug/l)	NA	30	13	43%	ND-2,000	25.0	61.3	174.3	0%
m&p-Xylenes	NA	30	9	30%	ND-7200	100.0	234.2	655.7	0%
o-Xylene	NA	30	6	20%	ND-2400	17.0	84.6	225.9	0%
Isopropylbenzene	NA	30	23	77%	ND-310	41.0	7.4	24.1	0%
N-Propylbenzene	NA	30	18	60%	ND-430	33.4	11.1	33.9	0%
1,3,5-Trimethylbenzene	NA	30	9	30%	ND-550	8.1	24.6	60.2	0%
1,2,4-Trimethylbenzene	NA	30	11	37%	ND-1200	20.0	45.2	106.0	0%
Sec-Butylbenzene	NA	30	22	73%	ND-160	40.0	5.6	15.4	0%
Naphthalene	NA	30	16	53%	ND-790	37.0	16.6	35.7	0%
Semi-Volatile Organics (mg/kg)									
Di-n-Octyl Phthalate	NA	36	35	97%	ND-21	21.0	0.6	3.5	0%
Naphthalene	NA	36	23	64%	ND-157.2	129.7	42.6	61.7	0%
Fluorene	NA	36	33	92%	ND-36	34.0	2.9	9.5	0%
Phenanthrene	NA	36	27	75%	ND-45.7	32.4	11.2	16.1	0%
2-Methyl Naphthalene	NA	36	16	44%	ND-410	89.0	74.6	116.9	0%

Table 12: Statistical Analysis of Transformed Data for Oily Sludges (tests with RT values only)

PARAMETER	Mean	Standard Deviation	Upper Confidence Interval Limit	Regulatory Threshold	UCL compared to RT
pH	7.72	0.01	7.82	12.50	UCL<RT
Sulfides	75.31 mg/kg	85.70	114.13 mg/kg	500.00 mg/kg	UCL<RT
Arsenic	25.63 mg/kg	6.26	31.42 mg/kg	TTLC: 500.00 mg/kg	UCL<RT
Barium	444.79 mg/kg	400.66	646.04 mg/kg	TTLC:10,000 mg/kg	UCL<RT
Beryllium	2.23 mg/kg	0.76	2.83 mg/kg	TTLC: 75 mg/kg	UCL<RT
Cobalt	22.59 mg/kg	7.48	28.57 mg/kg	TTLC: 8,000 mg/kg	UCL<RT
Chromium	31.96 mg/kg	7.44	38.99 mg/kg	TTLC: 2,500 mg/kg	UCL<RT
Copper	57.22 mg/kg	29.58	76.42 mg/kg	TTLC: 2,500 mg/kg	UCL<RT
Molybdenum	24.53 mg/kg	6.24	30.18 mg/kg	TTLC: 3,500 mg/kg	UCL<RT
Nickel	46.38 mg/kg	3.46	52.04 mg/kg	TTLC: 2,000 mg/kg	UCL<RT
Lead	91.15 mg/kg	160.21	151.00 mg/kg	TTLC: 1,000 mg/kg	UCL<RT
Selenium	8.54 mg/kg	0.17	9.06 mg/kg	TTLC: 100 mg/kg	UCL<RT
Thallium	27.99 mg/kg	4.43	33.02 mg/kg	TTLC: 700 mg/kg	UCL<RT
Vanadium	37.87 mg/kg	2.91	42.55 mg/kg	TTLC: 2,400 mg/kg	UCL<RT
Zinc	167.13 mg/kg	163.49	246.35 mg/kg	TTLC: 5,000 mg/kg	UCL<RT

Table 13: Detected Analytes in Foam Treatment Waste

PARAMETER	Regulatory Threshold	n	Tot. ND	%ND	Range	Median	Mean	SD	% above RT
pH	2 or lower; 12.5 or higher	2	0	0%	7.9-8.1	8.1	8.1	0.1	0%
Aquatic Toxicity (mg/l)	less than 500	1	0	0%	>500	NA	NA	NA	NA
TPH (mg/l)		2	0	0%	200-610	405.0	405.0	205.0	0%
Metals (STLC: mg/l)									
Barium	STLC 100	2	0	0%	1.50-1.80	1.7	1.7	0.2	0%
Copper	STLC 250	2	0	0%	1.60-320	2.4	2.4	0.8	0%
Lead	STLC 5.0	2	0	0%	1.20-1.70	1.5	1.5	0.3	0%
Selenium	STLC 1.0	2	0	0%	0.27-0.46	0.4	0.4	0.1	0%
Zinc	STLC 250	2	0	0%	26-28	27.0	27.0	1.0	0%

VIII. DISCUSSION OF RESULTS

1. Data Discussion

Four E&P wastestreams were sampled during the course of this initiative: produced water; drilling waste; oily sludges; and foam treatment waste. Due to the limited volume of foam waste available at the time of sampling, data pertaining to this wastestream was generated based on analysis of only two samples. Foam treatment data are discussed in this section, but a formal conclusion will not be drawn regarding the waste's characteristics based on limited data.

As previously stated in this report, the primary objective of this initiative was to examine and characterize the E&P wastes, and determine if they are properly managed in California. As such, each wastestream sampled is evaluated independent of the others to enable DTSC to draw general assumptions of each wastestream. All data points obtained for a particular wastestream are pooled together regardless of the sampling site to form a sample population representative of that wastestream. This approach is appropriate when considering the scope of this initiative, which was not to compare and contrast individual facility data, but to characterize and obtain information for the wastestream as a whole.

The sample population was noted to have a large variation, which generated a standard deviation value that is greater than the mean. Factors contributing to the large variation are regional differences in formations, and diversity of waste management practices among oil producers. Geological characteristics of each region will have specific, naturally occurring variations. To a large extent, a wastestream's composition will also be affected by the type of operation and waste management practices of the generator. For example, the benzene concentration in produced water samples varies from ND to 2,100 ug/l. It was noted that produced water samples that were collected from pipelines to the agricultural canal displayed the lowest benzene concentration, with values ranging from below detection limits to 0.6 ug/l. SCD attributes this finding to the purification processes that produced water is put through (e.g., water treatment plants), prior to disposal into the canal to meet standards imposed by RWQCB permits under which the water is disposed. Thus, the extent of treatment of the waste prior to disposal is a determining factor in the concentration of the contaminants. Because waste management practices vary with each facility, the contaminant levels in the waste will vary also. For some tests (e.g., SVOCs), a large variation occurred because the majority of samples analyzed displayed ND values, with few samples displaying values above detection limits. As a result of this variation, the calculated mean value was lower than the standard deviation.

The data generated during this initiative are evaluated in terms of the four hazardous waste criteria outlined in 40 CFR, Section 261.10 et seq., and 22 CCR Sections 66261.20 et seq., namely, ignitability, corrosivity, reactivity, and toxicity. Significantly, the State's toxicity characteristic incorporates the E&P exemption, as discussed in the Regulatory Background section this document. Thus, E&P wastes that exhibit the toxicity characteristic for hazardous waste based solely on TCLP remain exempted from regulation as hazardous wastes under State law. The exemption does not apply in California if toxicity of the waste is established under criteria other than TCLP, or the waste is hazardous by a hazardous waste characteristic other than toxicity.

SCD selected parameters of study for E&P wastes that would be indicative of the wastes' hazardous characteristics. The flash point is indicative of a waste's ignitability. The pH test is indicative of a waste's corrosivity. Measures of the waste's toxicity were obtained by performing tests for aquatic toxicity bioassay, BTX, VOCs, SVOCs, TPH, and metals. Reactivity was assessed by measuring the amount of hydrogen sulfide gas produced by acid digestion of sulfides present in the waste.

22 CCR, Sections 66261.21 et seq. establish RT values for the following tests: pH; aquatic toxicity; flash point; and metals. With few exceptions, the regulations do not list specific RT values for most volatile and semi-volatile organic compounds. Such an exception is benzene, with an established RT value of 0.5 mg/l, when extracted by TCLP.

The following is a discussion of results obtained as they relate to the four criteria for hazardous waste identification mentioned above.

Produced Water

Based on the data summarized in Table 7, produced water was not found to be hazardous for the characteristics of ignitability, corrosivity, reactivity, or toxicity. That conclusion is supported by the statistical calculations of transformed data for produced water listed in Table 8. For tests with an established RT value, the UCL value was calculated and compared to RT. The UCL is lower than RT for all applicable tests performed on produced water, which indicates that the produced water is not hazardous.

In general, produced water samples were found to display elevated levels of volatile organic compounds. For example, benzene varied in concentration from ND to 2,100 ug/l, in some cases exceeding the TCLP threshold of 0.5 mg/l (500 ug/l). Although the presence of benzene above RT levels would generally be sufficient to render a waste hazardous by the characteristic of toxicity under both Federal and State law, due to the E&P exemption, produced water and other

E&P wastes are not subject to regulation as hazardous waste Federally or in California.

Drilling waste

Based on the data summarized in Table 9, drilling waste generated during water-based drilling and aggregated with cement was not found to be hazardous. This conclusion is also made evident by the statistical calculations performed on transformed data, summarized in Table 10, which indicate that UCL was lower than RT for all applicable tests.

Drilling waste samples displayed elevated pH values, however not sufficient to exceed the RT value for the pH test, and therefore not sufficient to be classified as corrosive. pH values ranged from 8.7 to 11.5, approaching the RT value of 12.5. The alkalinity of the waste is attributed to the presence of cement used to aggregate the aqueous phase of the drilling waste. One concern regarding this practice was that cement, due to its alkaline properties, may act as a buffer during the acidic conditions of the extraction test in the laboratory and mask the true characteristics of the waste, especially its metal constituents.

Oily sludge

Data generated by the analysis of oily sludge are summarized in Table 11. Based on statistical interpretation of transformed data summarized in Table 12, oily sludge was not determined to be a hazardous wastestream overall. Although several individual samples met the characteristic for hazardous waste by exceeding established RTs, the sample population as a whole had UCL values lower than RT values for all applicable tests. However, oily sludge shows higher potential than other sampled E&P wastes for exhibiting hazardous waste characteristics not covered by the exemption, with ten out of a total of thirty-six samples found to be hazardous. Four oily sludge samples collected at facility no. 4 met the ignitability characteristic for hazardous waste by failing the flash point test; four samples collected at facility no. 3 met the toxicity characteristic for hazardous waste by exceeding the Total Threshold Limit Concentration (TTLC) for lead; and two samples collected at facility no.1 met the reactivity characteristic for hazardous waste by exceeding the U.S. EPA guidance threshold value for releasable sulfides. These findings are discussed in more detail as follows.

Ignitability characteristic of oily sludges

The flash point test, outlined in 22 CCR, Section 66261.21(a)(1) was used as a measure of ignitability for all samples collected. According to the regulations, any liquid waste containing less than 24 percent alcohol by volume is hazardous if it has a flash point of less than 140 degrees Fahrenheit. Four oily sludge samples out of thirty-five collected failed this test, with a flash point value of 65 degrees Fahrenheit, which renders them hazardous under California law. Note: The sludge samples had sufficient liquid content for the flash point test to be performed.

The four sludge samples were taken from a production pit at facility no. 4 in Los Angeles County. The facility operator indicated that some contents of the pit, namely the uppermost liquid layer would be extracted and recycled for its oil content. The lower layer, consisting of sludge would be shipped offsite to a commercial disposal facility. No clear separation existed between the portion of waste that was recyclable and the portion that would be stored and disposed. Due to the lack of separation among various phases of the waste and based on the results obtained, it was concluded that the oily sludge waste contained in the pit is hazardous in its entirety. Table 14 summarizes the flash point test values that led to that conclusion.

Table 14: Sludge Samples Exceeding Regulatory Threshold for Ignitability

Test: Flashpoint	Test result	RT	RT exceeded?
Sample 1	<65	<140 degrees Fahrenheit	Yes
Sample 2	<65	<140 degrees Fahrenheit	Yes
Sample 3	<65	<140 degrees Fahrenheit	Yes
Sample 4	<65	<140 degrees Fahrenheit	Yes

Does the E&P exemption apply?
No, because the hazardous waste determination was based on the ignitability characteristic for hazardous waste, not toxicity.

Reactivity characteristic in oily sludges

The reactivity of a waste is assessed by the releasable sulfide test. In the absence of a regulatory threshold value for releasable sulfides in 22 CCR, an interim guidance value was established by the U.S. EPA in the SW-846 manual, Chapter 7, at 500 mg/kg hydrogen sulfide for solids and 500 mg/l for aqueous waste. This guideline threshold value was exceeded by two out of thirty-five sludge samples analyzed. Four sludge samples were collected from the bottom of a water-holding tank (waste also known as tank bottoms) at facility no.1 in Los Angeles County. Two of the four samples collected at this site exceeded the regulatory guidance value for releasable sulfides, as summarized in Table 15.

Table 15: Sludge Samples Exceeding Regulatory Threshold for Sulfides

Test: Sulfides	Test result	RT (guidance value)	RT exceeded?
Sample 1	416 mg/kg	500 mg/kg	No
Sample 2	440 mg/kg	500 mg/kg	No
Sample 3	688 mg/kg	500 mg/kg	Yes
Sample 4	640 mg/kg	500 mg/kg	Yes

Does the E&P exemption apply?
No, because the hazardous waste determination was based on the reactivity characteristic for hazardous waste, not toxicity.

Toxicity characteristic of oily sludges

Toxicity of the waste samples was assessed through VOCs, SVOCs, TPH, BTX, aquatic toxicity bioassay, and metals analyses.

As was the case with produced water, VOCs were found at elevated concentrations in oily sludges. SVOCs and some chlorinated organic compounds were also present in low concentrations. The presence of chlorinated organic compounds may be an indication that solvents or other fluids that did not originate in the natural formation became part the wastestream. Such fluids are covered by the E&P exemption, according to guidance provided by the U.S. EPA, as long as they become part of the production stream and are co-produced with the oil, as discussed in the Regulatory Background section of this document.

Both produced water and oily sludges had elevated VOCs and SVOCs concentrations which would generally be sufficient to render them hazardous under the toxicity characteristic for hazardous waste summarized in 22 CCR, Section 66261.24(a). However, a hazardous waste determination is not appropriate in this case because in California, E&P wastes remain exempt from regulation as hazardous when toxicity is determined based solely on TCLP.

The State regulations also establish Total Threshold Limit Concentration (TTLC) and Soluble Total Limit Concentration (STLC) values, which, if exceeded by the constituents in a waste, render that waste hazardous under State law. STLC and TTLC values were obtained for metals and compared to standards outlined in 22 CCR Section 66261.24(a)(2). Four samples out of thirty-five met the criteria for hazardous waste by exceeding the TTLC value for lead.

The four oily sludge samples were collected from a pump cellar trough at facility no. 3 in Los Angeles County. Based on information supplied by the facility operator, that waste consisted mostly of leakage of oily emulsions from the pumps, mixed with drainage water from the pump cellar floor. Table 16 summarizes the TTLC values for lead obtained during metals analysis.

Table 16: Sludge Samples Exceeding Regulatory Threshold for Lead

Test: TTLC	Test result	RT	RT exceeded?
Sample 1	2,200 mg/kg	1,000 mg/kg	Yes
Sample 2	2,000 mg/kg	1,000 mg/kg	Yes
Sample 3	1,800 mg/kg	1,000 mg/kg	Yes
Sample 4	1,600 mg/kg	1,000 mg/kg	Yes

Does the E&P exemption apply?
No, because the E&P exemption only applies if toxicity of the waste is determined based on TCLP results. In this case, toxicity was determined based on TTLC, a criterion not covered by the exemption.

Foam treatment waste

Foam treatment data obtained was not sufficient to support a formal conclusion or statistical evaluation because the number of samples analyzed was only two. However, the data summarized in Table 13 show extremely low concentrations of most analytes in the two samples. This finding is viewed by SCD as an indication that foam treatment waste does not exhibit any hazardous waste characteristics.

2. Conclusion

Samples of produced water, drilling waste, oily sludge, and foam treatment waste were collected and analyzed for characteristics of hazardous waste, based on the four hazardous waste characteristics outlined in 40 CFR, Sections 261.10 et seq., and in 22 CCR, Sections 66261.20 et seq., namely ignitability, corrosivity, reactivity, and toxicity. The following conclusions were reached as a result of data interpretation.

The E&P wastestreams sampled and analyzed during this study were not found to be hazardous under current Federal and State law. Although produced water and oily sludges meet the Federal toxicity characteristic for hazardous waste, they are exempted from regulation as hazardous pursuant to the E&P exemption. However, oily sludges showed potential to display hazardous waste characteristics by criteria other than TCLP, with ten out of thirty-six samples displaying hazardous waste characteristics under State law. Based on the data obtained, it is concluded that some oily sludges may exhibit hazardous waste characteristics not covered under the E&P exemption, in which case oily sludges should be managed as hazardous wastes in California. Because of the limited number of samples found to be hazardous, it is plausible that those hazardous characteristics of the oily sludges were largely due to factors such as facility operations and waste management practices. Foam treatment waste data was not sufficient to support statistical evaluation and a formal conclusion, because the number of samples analyzed for each test was only two. However, the extremely low concentrations of most analytes in the two samples are viewed by SCD as an indication that foam treatment waste does not exhibit any hazardous waste characteristics.

The data indicate that depending on circumstances such as formation characteristics or facility operations, certain E&P wastes, such as oily sludges, may exhibit hazardous waste characteristics not covered by the exemption in California. Such wastes cannot be managed as non-hazardous under the E&P exemption, and, although exempted at the Federal level, are subject to State laws applicable to hazardous waste. It is the generator's responsibility to determine which wastestreams are hazardous in California and manage them accordingly.

3. Limitations of study

The study summarized in this report was conducted under the following limitations.

This study was limited by its scope, which was to sample those wastestreams that are most prevalent in the oil production industry and presumably would pose the greater hazard to human health and the environment if found to be hazardous. Other, lower volume wastes associated with oil production remain of interest to DTSC due to their potential to exhibit hazardous characteristics.

Another limitation occurred because sampling did not include all regions where oil production takes place in California. However, the study is diversified enough to obtain an overview of E&P wastes for DTSC's purposes. The study was designed to include oil production in both highly populated urban settings, represented by Los Angeles County, and oil production in a rural area, represented by Kern County, where urban encroachment on the oil fields is not prevalent.

Limitations existed in terms of number of samples that could be analyzed by the laboratories during the sampling episodes. However, for purposes of this initiative, a sufficiently large number of samples was collected and analyzed to obtain an overview of the wastestreams of interest.

4. Special concerns

Field observations and information provided to DTSC by facility operators regarding E&P waste management practices raised the following concerns.

1. VOC releases into the atmosphere from aerated production pits containing oily sludge waste are a concern.

2. Although in small amounts, the presence of chlorinated compounds in some E&P wastes raises a question regarding the extent to which the presence of such compounds would render the wastes hazardous.

3. The presence in high concentrations of VOCs and some SVOCs in produced water may pose a concern. However, produced water disposed into public works is regulated under the RWQCBs. Thus it was noted during the course of the study that produced water with high VOC levels was typically recycled in a closed system and used for waterflood, not disposed into public works.

4. The practice of using cement to aggregate drilling waste is a concern, because cement may dilute the waste by masking metal constituents in laboratory test conditions.

5. The use of oily sludge for fabrication of road mix is a concern because that practice is essentially use of waste in a manner constituting disposal by land application, as defined in 22 CCR Section 66261.2(d)(1)(A). It is not clear from this study if facilities engaged in road mix fabrication are conducting that practice in accordance with the provisions of 22 CCR Section 66266.21, which sets forth requirements for recyclable materials that are placed on the land. If standards set forth in 22 CCR Section 66266.21 for land application were not met, the waste would remain subject to full regulation under hazardous waste laws and regulations.

The oil exploration and production industry addressed DTSC's concerns in a memorandum prepared by the Western States Petroleum Association (WSPA). WSPA's responses are cited below.

1. "VOC releases to atmosphere from aerated production pits would appear to be more a concern of local air quality management districts than of the Department. We also question whether any of these wastes would be present in "production pits", which in most cases are actually concrete or steel tanks. Under the HWCL, residues that form in the bottom of product or raw material storage tanks of other process equipment are not subject to regulation until removed from the unit (22 CCR § 66261.4 (c))".

2. “The potential presence of chlorinated compounds in some E&P wastes may or may not be an issue, depending on the constituent. Many chlorinated compounds regulated under the TCLP and as such would fall under the limited E&P exemption available under state law”.

3. “As noted in the report, a substantial percentage of produced water is beneficially reused in enhanced oil recovery operations. Produced water that is discharged to surface waters, POTWs or otherwise applied to land (e.g., discharged to evaporation ponds) is regulated by the regional water quality control boards, local POTWs or other state or local agencies, and must meet applicable discharge limits prior to disposal. We are not aware of any situation in which VOCs or SVOC in produced water have posed an environmental concern.”

4. “Drilling wastes are nonhazardous even prior to aggregation with cement for purposes of stabilization. Confirming data are available”.

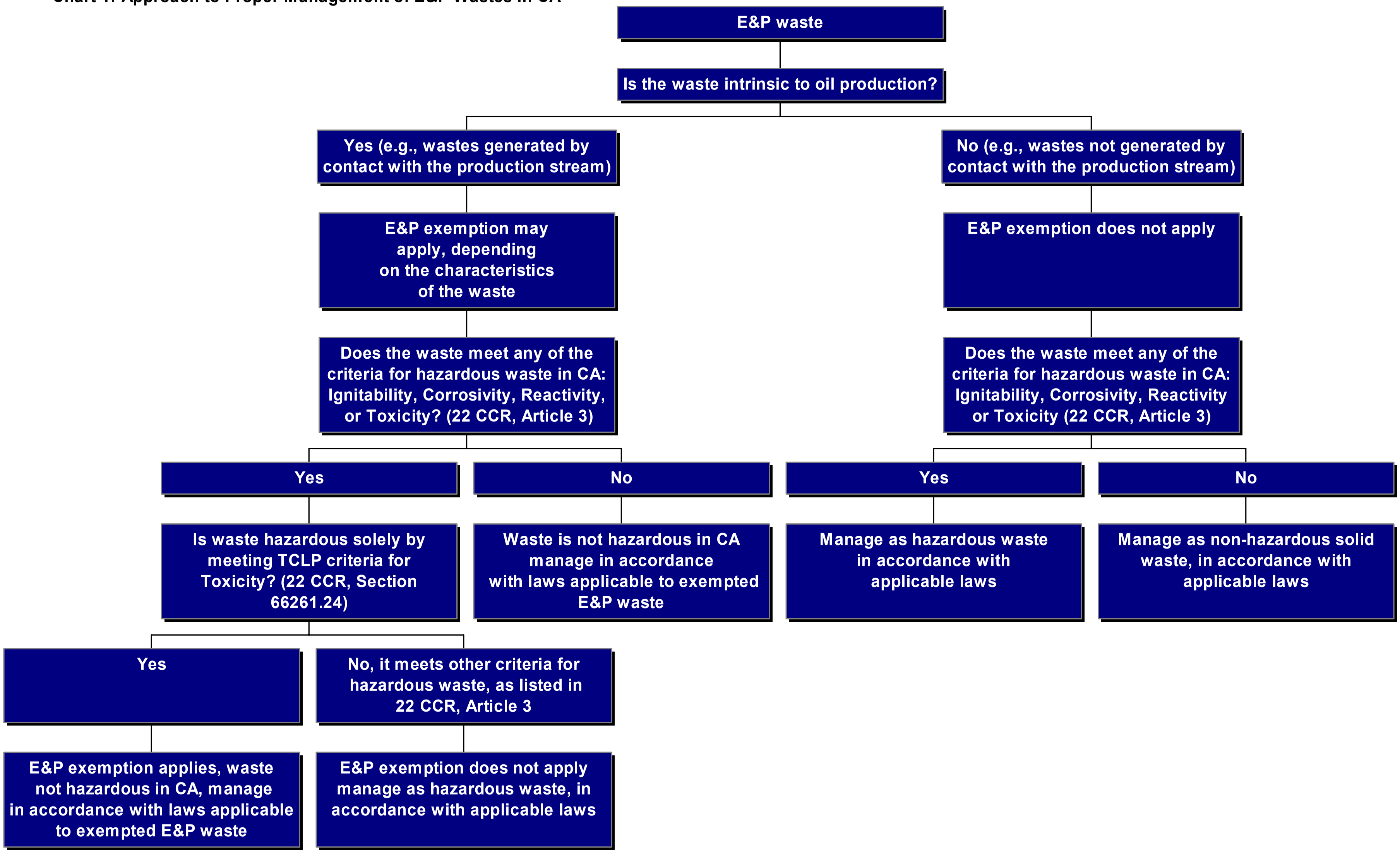
5. “Over the years, WSPA has been extensively involved in the development of regulatory requirements applicable to roadmix operations. As you are aware, DTSC along with other Cal-EPA agencies participated in a Task Force study entitled “Cal/EPA Exploration and Production Regulatory Task Force, Beneficial Reuse of Nonhazardous Oil-Field Road Mix Clarification of Regulatory Issues, March 1999”. A formal Cal/EPA report was issued in March 1999. The Task Force reviewed many aspects of the Beneficial Reuse of Nonhazardous Oilfield Road mix materials. The Report cited that guidelines developed by the Industry which clearly recognize the hydrocarbon-containing materials for use in oilfield road mix must be characterized as “nonhazardous”.

5. Recommendation

The study shows that, depending on circumstances of production, certain E&P wastestreams may exhibit hazardous waste characteristics not covered under the E&P exemption. Although exempted from regulation as hazardous wastes at the Federal level, those E&P wastes are subject to regulation as hazardous in California and cannot be managed as non-hazardous under the Federal E&P exemption. DTSC should emphasize that oil production facilities, as potential generators of hazardous wastes, must ensure proper disposal of their wastes, in accordance with standards for waste characterization set forth in 22 CCR, Section 66262.11, as well as meet other standards applicable to generators of hazardous wastes provided under 22 CCR Section 66262.10 et seq.

Chart 1 is a flow diagram depicting one approach to achieving proper management of E&P wastes in California.

Chart 1: Approach to Proper Management of E&P Wastes in CA



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X. GLOSSARY OF TERMS

Class II Injection Well
A well that injects fluids brought up to the surface in conjunction with production of oil, and natural gas (where applicable). Class II wells are used for disposal or enhanced recovery

Downhole equipment
Equipment placed inside the casing and at the bottom of a producing well, for the purpose of pumping and transporting the oil to the surface

Drilling Bit
The rotary cutting device connected to the end of the drilling pipe, and used to cut through soil and rock during drilling

Drilling Rig
A multi-component structure used in drilling to stack drilling pipe; the drill rig platform (or floor) is the place from where the drilling equipment is operated

E&P Waste
Wastes produced by the oil and natural gas exploration and production

Enhanced Recovery
Process by which the oil production is stimulated by injection of water or steam into the producing formation

Oil Exploration
Activities undertaken to identify geological formations that contain oil

Oil Production
Activities undertaken to extract (or produce) the crude oil from the ground, and remove excess water and other unwanted materials

Oil Well
A wellbore that has been completed and ready to produce oil

Production Facility
Site where crude oil production takes place

Production Pit
As used in this report, production pit refers to pits found at production facilities and used mainly for storage of sludge waste

Steamflood
Injection of steam for enhanced oil recovery

Waterflood
Injection of produced water for enhanced oil recovery

Wellbore
The hole created by the drilling bit during drilling; if completed the wellbore will become a well

Well casing
Hollow steel tubing placed inside the wellbore, to maintain the integrity of the future well and house the production piping

Well completion

Process by which a freshly drilled wellbore is finalized into becoming a well

Workover

General term describing an array of well treatment operations intended for the general maintenance of the well, or to restore or improve production.