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ABSTRACT

During this reporting period our project focused on (1) review of case studies of remediation of centralized and commercial drilling fluid disposal (CCDD) sites in Texas, and (2) information transfer with preparation of a proceedings paper and a workshop/short course.

Texas remediation of certain drilling-fluid disposal sites includes examples at CCDD sites as well as commercial oil reclamation sites and saltwater disposal sites that also disposed of drilling fluids in pits. Site investigations range from qualitative visual inspection and assessment to comprehensive hydrodynamic, chemical, and geophysical analyses of wastes and groundwater. A range of techniques has been used to evaluate waste material, soil, groundwater, and surface water for potential contamination with hydrocarbons, chemicals, saltwater, and naturally occurring radioactive materials (NORM). Most constituents of concern measured in these studies are below regulatory action levels and established guidelines.

A proceedings paper summarizes results presented in this and previous semi-annual progress reports will be part of the Transactions of the Gulf Coast Association of Geological Societies (GCAGS). A technology transfer workshop also was prepared as part of that Annual Meeting of the GCAGS to be held in November 2002.

INTRODUCTION

This study is a compilation and summary of information on active and inactive centralized or commercial drilling-fluid disposal (CCDD) sites in Louisiana, New Mexico, Oklahoma, and Texas. The objective of the analysis of these sites is to gain insight into the probable characteristics or behavior of contaminants at poorly documented abandoned CCDD sites. Available information being reported in this study includes number and acreage of pits, waste volume, groundwater-level elevations, and concentrations of selected constituents in waste material, surface water in associated pits, and groundwater beneath the site. For many sites, dated constituent analyses for specific monitoring wells are available for time-series mapping and graphing of variable concentrations.

This research is developing and evaluating a multi-state technical database on the abandoned CCDD sites in these four states to improve regulation, site assessment, and remediation procedures for these types of sites. Although current approved permits address the operation and closure of present day CCDD sites, many older sites were operated under less stringent permitting requirements. Abandoned sites may have received wastes other than spent drilling fluids and may have been abandoned without proper closure. Information compiled from well-documented disposal sites can be used to predict the quantity and character of constituents and can be used to prioritize additional studies at poorly documented abandoned facilities more accurately and efficiently.

Analysis of this multi-state database attempts to answer several critical questions:

- How many abandoned CCDD sites are there in the four-state region?

- What data have been most frequently collected at CCDD sites that pertain to potential contamination of soil and groundwater?
- What constituents of concern (COC) such as metals, salt, and hydrocarbons are found in the waste and groundwater?
- How mobile are these COCs, and is there evidence for excursion?
- What is the most cost-effective approach for investigating such sites?
- Is site remediation typically necessary and, if so, under what conditions and what is the most cost-effective approach?

Pooling data on CCDD sites from these four states increases the statistical sample size from which conclusions may be drawn.

This semi-annual progress report focuses on techniques for assessment and remediation that have been recommended and used for CCDD sites in Texas that are under the jurisdiction of the Railroad Commission of Texas (RRC). The goal is to inventory approaches that have been used and to show the incidence of sites at which States have determined either remediation or no action with monitoring were warranted.

The Railroad Commission of Texas (RRC) has statutory responsibility under Senate Bill 1103 (72nd Legislature, 1991) for cleanup of abandoned disposal sites related to oil and gas exploration and development (E&P) in Texas. Sites prioritized for assessment include abandoned CCDD sites. Centralized sites receive drilling wastes from several E&P sites under one operator or from several operators under common agreement. Independent operators for a profit manage commercial sites. Also included in this review are commercial sites that reclaimed oil from saltwater, many of which disposed of drilling-fluid wastes in on-site pits.

This review focuses on 12 cases documented in RRC files for which potential environmental impacts of specific sites were assessed by the RRC or its contractors, and for which recommendations for remediation measures were developed. Remediation measures, when deemed necessary, were undertaken for many of these sites. Most CCDD sites are still in the assessment phase.

We have also looked at remediation case histories in Oklahoma. Data for nine out of ten abandoned CCDD sites in the Oklahoma database indicate that after assessment by an environmental consulting company subcontracted by the State, none evidenced environmental conditions warranting additional corrective measures. Site-specific information on procedures used prior to final closure of these CCDD sites in Oklahoma, such as de-watering and back filling of pits, were not discussed in available file documents. It is likely these remediation procedures were not employed at the time information was gathered. No data on remediation of abandoned CCDD sites in Louisiana or New Mexico were available.

Many CCDD sites in the four States have samples of pit water or groundwater or both with chloride concentrations that exceed both the EPA aesthetic secondary maximum contaminant level (SMCL) (250 mg/L) that is unenforceable and total dissolved solids (TDS) contents that exceed the Underground Sources of Drinking Water (USDW) limit (10,000 mg/L) used for public water systems that is enforceable. Some undocumented CCDD abandoned sites may also have levels that exceed these SMCL and TDS criteria. Applicable regulations do not require such sites, based solely on these criteria, to be remediated mainly because these chloride levels are normally not health based, but aesthetically based. In addition, available site data do not generally show what

is the ambient concentration in the adjacent environment and whether these constituent concentrations reflect contributions from onsite or from offsite. Remediation decisions for specific CCDD sites may require collection of additional onsite data on shallow groundwater quality and background data from upgradient of site operations. CCDD sites in Louisiana, New Mexico, Oklahoma, and Texas at which average concentrations of chloride and TDS exceed chloride and TDS criteria are listed in table 1.

TEXAS REGULATION OF OIL AND GAS DRILLING WASTES

The 1980 Solid Waste Disposal Amendments to the Resource Conservation and Recovery Act (RCRA) exempted drilling fluids, produced water, and associated wastes from regulation as Subtitle C hazardous wastes (table 2). In 1988, the Environmental Protection Agency (EPA) confirmed the appropriateness of this exemption and decided not to recommend federal regulation of E&P wastes as hazardous wastes under Subtitle C of RCRA. The main reasons were: (1) Subtitle C does not provide flexibility to consider cost; (2) existing state and federal regulatory programs are generally adequate for controlling oil and gas wastes; (3) permitting delays would hinder oil and gas development; (4) Subtitle C regulation of these wastes could severely strain Subtitle C facility capacity; and (5) it is impractical and inefficient to implement Subtitle C for all these wastes (U.S. Environmental Protection Agency, 1988, p. 25453).

In general, E&P exempt wastes are generated in “primary field operations”. Primary field operations include activities occurring at or near the wellhead and before the point where the oil is transferred from an individual field facility or a centrally located facility to a carrier for transport to a refinery. It includes exploration, development, and the

water separation, de-emulsifying, degassing, and storage at tank batteries associated with a specific well or wells, are examples of primary field operations. In 1993 EPA clarified the scope of the E&P exemption for waste streams generated by crude oil and tank bottom reclaimers, oil and gas service companies, crude oil pipelines and gas processing plants and their associated field gathering lines (U.S. Environmental Protection Agency, 1993). EPA stated that certain waste streams from these operations are “uniquely associated” with primary field operations and as such are within the scope of RCRA Subtitle C exemption. EPA’s clarification cautioned, however, that these wastes might not be exempt if they are mixed with non-exempt materials or wastes, listed in table 3.

Statutory authority for the RRC to regulate the oil and gas industry and protect freshwater date from 1919 with passage of a law by the Texas Legislature giving the RRC broad enforcement powers (Interstate Oil and Gas Commission, 1993). Since 1919 RRC promulgated a number of Rules for protection of environmental quality. Rule 8 addresses water protection as part of E&P operations and Rule 91 covers cleanup of soil contaminated by a crude oil spill. Rule 8 requires that any method of disposal of any oil and gas waste not authorized by rule be permitted. Senate Bill 1103 (72nd Legislature, 1991) gave the RRC additional responsibility for cleanup of abandoned disposal sites related to oil and gas exploration and development (E&P) in Texas. Rules 8 and 91 sometimes are used as guidance for abandoned CCDD sites. No specific criteria have been established in rule for closing of CCDD sites. Disposal at municipal landfills is subject to additional criteria of constituent limitations (table 4). Rules 8 and 91 do not indicate that TPH or saltwater impacted media be removed from an impacted site to a permitted facility.

Rule 8 specifies chloride concentration for landfarming and burial of drilling fluid and associated cuttings authorized by rule. Generally, RRC-issued permits for CCDD sites and landfarming sites have a chloride concentration limit of 3000 mg/L. Rule 8 does not specify a generally allowable chloride concentration for drilling-fluid disposal. Rule 8 also does not specify a TPH limit for E&P waste. The RRC does not object to the disposal of oil and gas waste at a TCEQ facility provided the TCEQ concurs and documentation regarding the shipment of waste is submitted by the operator to the district office following the disposal (J. Hybner, 2003, written communication). The latest guide for disposal of oil and gas waste to TCEQ municipal landfills was updated in 1999. The guide states that the chloride concentration is considered on a case-by-case basis and does not require a chloride concentration of less than 3000 mg/kg. In addition, oil and gas wastes disposed of in TCEQ municipal landfills do not have to test for all analytes shown in table 3. For example, the 1999 guide referenced above indicates that drilling muds require testing for barium, TPH and BTEX (J. Hybner, 2003, written communication).

Rule 91 specifies TPH limits that apply to the cleanup of soil in non-sensitive areas contaminated by crude oil spills. While not applicable to CCDD sites, these limits have been mentioned for comparison in the evaluation of waste materials at CCDD sites. Rule 91 applies to the clean up of soil contaminated by crude oil spills (J. Hybner, 2003, written communication).

Although rules do not mandate analyses of RCRA non exempt waste, Rule 98 requires a person who generates an oil and gas waste determine whether such waste is nonhazardous either through testing or process knowledge. Any permit issued for non-exempt waste requires that whether waste is nonhazardous be determined by testing.

Although pits may be in compliance with State regulations, operators of disposal sites may not be exempt from civil liability for waste constituents in the event of sale of the property or discharge or excursion of pit materials, including impacted groundwater, to adjacent properties. For these reasons operators often have pit wastes analyzed for constituents, especially certain metals, in addition to TPH and chloride.

SITE ASSESSMENT AND CLEANUP OF CCDD SITES IN TEXAS

Texas case examples may include aspects that are representative of abandoned CCDD sites both in Texas and elsewhere. Methods suggested or used for assessment and remediation also may be illustrative of present practice where environmental impacts are not great. Site complexity ranges from a single small pit at some sites to large, multi-pit facilities that also included oil-reclamation and saltwater disposal operations.

Remediation requirements range from cases where no immediate action was found to be warranted to cases where complete dismantling of tanks, plumbing, and buildings along with extensive excavation and export of contaminated sludge and soils, and landscaping was required.

Since 1991, RRC personnel have identified and inventoried abandoned oil-field sites as candidates for cleanup. The RRC ranked sites by giving priority to contaminated sites that (1) have had observable releases, (2) occur in groundwater recharge zones with high soil permeability, (3) lie near surface-water bodies or water-supply wells, or both, (4) have high public profile and have received complaints, and (5) are near population centers. Straightforward solutions for cleanup are readily apparent for many of the sites. In the simplest cases inspection by RRC may be sufficient to satisfy requirements for

environmental security of a site. In more complex cases consultants are contracted for site

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assessment, determination of required remediation procedures, and estimate of cleanup costs.

Texas oversight of assessment and cleanup of CCDD sites is focused on assuring environmental security of the site, such that adjacent soils, surface water, and groundwater will not be contaminated after closure. Assessment of need for remediation at abandoned CCDD sites in Texas has used multiple guidelines drawn from State regulations and the U. S. EPA. Guidelines applied in Texas are from the RRC and the TCEQ (formerly Texas Natural Resource Conservation Commission), including health-based standards (TNRCC, 1996, 1998, 1999; U.S. EPA, 1996a, b). For example, the TPH standard of 1 percent dry weight mandated for crude-oil spills in non-sensitive areas (Rule 91) might be used as a guideline for determining whether specific remediation activities at a CCDD site is warranted, although the standard as written does not apply to such sites. Likewise, although Rule 8 does not specify a chloride concentration for drilling-fluid disposal, RRC-issued permits for landfarming sites generally stipulate a chloride concentration limit of 3000 mg/L. That limit might be taken as a guideline for consideration in closing a CCDD site.

Examples of Abandoned Texas Sites

The 12 sites discussed below represent a range of environmental categories and remediation applications. These sites do not make up a historically exhaustive list of abandoned CCDD sites in Texas but include well documented sites described in RRC remediation files. These sites have been abandoned over the last 20 years or more. Before 1984, CCDD sites operated under less stringent rules or guidelines. Many operators of those sites and of proposed sites where pits had already been excavated applied for RRC

permits in 1984, but were refused for a variety of reasons. The RRC ordered CCDD operators to dewater, backfill, and close pits at many of these sites. Although not technically abandoned, the environmental impact of these sites is not well known. Such sites, where identified, are included in the tally and statistics of sites (Dutton, 2002; Nance and Dutton, 2002). Examples are presented in order of the apparently least complicated to the most complex.

Albany Tank Yard

The Albany Tank Yard site (fig. 1a) was 0.5 mi north of the North Fork of Hubbard Creek near Albany, Shackelford County, Texas. This abandoned oil reclamation site included six sludge pits, nine 110 to 500 bbl storage tanks, some equipment, and metal buildings that served various purposes. The site was permitted in September 1982. Beginning in 1992, there was a history of permit violations such as leaking tanks, improper discharge of basic sediment and sludge, chemicals leaking from containers, and debris piles. A site assessment in June 1999 included onsite environmental sampling followed with chemical and laboratory analyses of COCs. Comparison of chloride, TPH, BTEX, barium, and arsenic in sludge at the Albany site to all sites in the study sample is shown in figure 1b-f. Site constituents generally are near the mean of all CCDD sites in the sample set, except sludge BTEX and sludge TPH that may be somewhat above the mean.

Pit waste had levels of chloride at (3,270 to 10,845 mg/L) and TPH (as much as 15.2 percent). Lead (average of 551 mg/kg) and arsenic (average of 37.2 mg/kg) exceeded TCEQ limits such that TCLP tests would be required to characterize waste prior to approval for disposal in a municipal landfill under TCEQ authority.

Benzo[a]pyrene (estimated at 3 mg/kg) exceeded the TCEQ risk-reduction program residential Tier 1 level (TNRCC, 1999). Monitor wells were dry and not sampled.

Recommendations for remediation included excavation and removal of impacted soil; disposal of debris and scrap metal; cleaning, dismantling and disposal of metal tanks; and excavation and removal of 2,400 yd³ of soil to a depth of 7 ft from the sludge area. Further assessment of the site is ongoing. State expenditure for site investigation activities is approximately \$138,700.

Briggs Site

The Briggs site (fig.2a) is an abandoned site east of Bay City, Matagorda County, Texas (Sullivan and others, 1999). The site consists of 1 pit with an areal extent of 7.2 acres (312,500ft²) and an adjacent outwash area. The site has three monitoring wells located along the pit berms.

Figure 2e-g compares chloride in groundwater and sludge and arsenic in sludge at the Briggs site to all sites in the study sample. These site constituents are near the mean of other CCDD sites. Chloride in groundwater (fig. 2a) is less than 1,000 mg/L and decreases across the site. Dissolved chloride in groundwater exceeds the SMCL unenforceable aesthetic guideline for chloride in public water systems (250 mg/L). However, lack of offsite background chloride data precludes determination of an onsite source; the Beaumont Formation soil in that part of the coastal plain can have elevated chloride content (Dutton, 1994). The water-level map (fig. 2d) indicates a uniform gradient from the three monitoring wells and a local potential for flow toward the north that may be influenced by pumping to dewater an adjacent sand quarry.

Samples of pit sludge were collected on a regular grid across the site and not composited prior to analysis in order to assess spatial variability. Distributions of chloride and arsenic in the waste material (fig. 2d, c) confirm that constituents are nonuniformly distributed with locally elevated concentrations of chloride (average of 6,600 mg/kg, maximum >10,000 mg/kg) and arsenic (>2 mg/kg). The RRC guideline for land treatment of arsenic is 40 mg/kg; therefore the onsite arsenic concentration posed no immediate environmental hazard. The outwash area also shows variation in chloride and arsenic levels at lower concentrations than the main disposal pit. The outwash area may be analogous at other sites where there has been a breach in pit berm and some migration of pit contents.

Assessment techniques used at the site included monitor well installation, water-level measurement, groundwater sampling, borehole and surface geophysical (EM) surveys, piston coring to sample the waste package and soils, a survey of naturally occurring radioactive materials (NORM) at ground surface, and a survey of area domestic wells. EM surveys showed minimal elevated ground conductivity suggesting there was no excursion of saltwater from the site. The EM survey did indicate a zone of elevated conductivity immediately beneath the site that appears to extend to a depth of 26 ft. Chromium and lead were detected in the waste material and in soils in a portion of the outwash area with concentrations above allowable limits for landfill disposal. The wastes exhibited low content of organic compounds and metals as measured by Toxicity Characteristic Leachate Procedure (TCLP) tests. Concentrations of organics and metals in soils did not exceed health-based criteria. Cadmium, lead, and chloride were detected above regulatory guidelines in onsite groundwater. However, it was concluded that

groundwater required no remediation because there is little likelihood of contamination of nearby domestic wells, completed at greater depths in aquifers separated from the shallow groundwater.

Primary factors to be considered in remediation were the low compressive strength of the waste package and the elevated chloride levels. The site poses some potential physical hazard because as the 3- to 7-ft thick waste package has very little load-bearing strength. It was determined that the estimated 39,000yd³ waste package would require 48.4 acres for land farming, larger than the property dimensions. A recommended remediation option for the site was installation of an engineered soil-geomembrane cap to isolate the waste package from leaching by rainwater, coupled with continued monitoring, including installation of additional monitoring wells. These and other options were concluded to be impractical because of expense and not justified by constituent concentrations. Site monitoring is ongoing to determine whether any change in conditions warrant further action.

T. L. Carter Site

The Carter site is 4.5 mi southeast of Roby, Fisher County, Texas. It received basic sediment, produced water, and drilling fluid. The site contained five unlined pits of various sizes ranging in capacity from 3400 to 10,600 bbl. Depth to groundwater is approximately 20 ft, and distance to surface water, the Clear Fork of the Brazos River, is 1500 ft. A 1984 permit application was denied by RRC and closure of pits was ordered. In 1991 pits were still open; by 1993 only 1 pit had been partly backfilled. Close proximity to surface water and lack of space to dispose of pit materials by land treatment complicated efforts to backfill the pits. File information contained no data on waste or

groundwater constituent concentrations. A preliminary cost estimate by RRC for remediation was approximately \$48,000. Assessment of the site is still in progress.

Fox Vacuum Site

The Fox Vacuum site (fig. 3a) is an abandoned site located 8 mi north of Buna, Jasper County, Texas. The site was used as a washout yard for trucks operated by an oil-field vacuum-service company and as a disposal site for waste drilling fluids. The site was probably abandoned around 1985 (Dutton and others, 1995). The site included 7 disposal pits with a combined areal extent of approximately 0.5 acres (22,233 ft²) that contained an estimated 3,000 yd³ (14,426 bbl) of crude-oil contaminated drilling mud. There were no monitoring wells at the site.

Comparisons of the Fox Vacuum site to all sites in the study sample for chloride, TPH, barium, BTEX, and arsenic in sludge are shown in figure 3b-f. Concentrations of sludge chloride, barium, and arsenic appear greater than the mean of other sites. There was no evidence that constituents from the site had affected a well located 350 ft east of the site. Wastes contained chloride concentrations of <3,000 mg/L and TPH concentration of <1 percent (Dutton and others, 1995). Remediation actions undertaken for the site included mixing contents of the 7 pits with berm material and clean soil, backfilling the pits, and leveling and compacting. State expenditures for site clean up, including other actions besides pit remediation, was approximately \$13,000.

Gober Disposal Site

The Gober Disposal site (fig. 4) near Bridgeport, Wise County, Texas, was a low chloride (<3000 mg/L) drilling fluid CCDD site located on the north side of the

1991. Few details on the facility are available at the time of this study. Site maps showed three irregularly shaped pits and a residential dwelling. Pit sizes were not determined since site maps lacked a map scale. The site was described as overgrown with trees and shrubs. Inspections in 1989 noted several permit violations including excessive chloride content in pits (15,000 mg/L).

Figure 4b compares pit-water chloride sampled at the Gober site to all sites in the study sample; the mean measured value of 2,966 mg/L is similar to the mean of other sites. A June 1990 RRC memo noted that natural degradation of the oil was in progress and suggested that no further cleanup was required. However, an April 1999 memo noted new violations including disposal of oil- and saltwater-contaminated drilling mud in unauthorized pits and pits permitted to receive only low chloride drilling fluid. The owner spread hay on remaining wastes to adsorb oil. The site was never reopened.

Manvel Saltwater Disposal Site

The Manvel Saltwater Disposal site (fig. 5a) is an abandoned site located within the city limits of Manvel, Brazoria County, Texas (Kaiser and others, 1996). The site is a former saltwater disposal site in which crude oil and drilling waste have also been disposed. The site consists of 4 main waste disposal pits. Two main waste-disposal pits (A and B, fig. 5a-d) covered approximately 4.17 acres (181,448 ft²) and two smaller ponds (C and D) that might have been waste disposal pits covered approximately 0.75 acres (32780 ft²). Monitoring wells include 14 wells completed in an upper water-bearing zone, 4 wells completed in a deeper zone, 6 shallow monitoring wells about the site perimeter, and 8 offsite shallow monitoring wells. Of the 4 deep wells, 3 are located along the periphery and one is located within the site. There is a plugged saltwater

disposal well and a plugged oil well on site. (Kaiser and others, 1996; Duke Engineering Services, Inc., 2001a).

Comparisons of chloride in groundwater and TPH, BTEX, barium, and arsenic in sludge at the Manvel site to all sites in the study sample are shown in figures 5e-i. Concentration of chloride in groundwater (fig. 5a, e) is more than 75,000 mg/L at the southeast side of the site and mean chloride (12, 715 mg/L) appears greater than the average for all sites. Groundwater exceeds the SMCL unenforceable aesthetic guideline for chloride in drinking water in 12 of the shallow monitoring wells and exceeds the USDW limit for TDS in 8 of the shallow monitoring wells. Barium levels in groundwater are highest (16 mg/L) toward the eastern side of the site (fig 5b). Barium in sludge (mean of 53,775 mg/kg) appears to exceed the average for all sites in the study sample and exceeds the TCEQ risk-reduction program residential Tier 1 level (TNRCC, 1999). Benzene levels in groundwater are highest (60.7 µg/L) just north of the disposal pits and appears to form a plume that is centered around the plugged oil well (Duke Engineering Services, Inc., 2001a). The TCEQ residential Tier 1 level for groundwater ingestion (TNRCC, 1999) for benzene is 5 µg/L. Benzene concentration appears to have decreased over time (Duke Engineering Services, Inc., 2001a). Samples collected from sludge in the 2 disposal pits showed TPH levels up to 4.1 percent, with an average of 1.2 percent (Kaiser and others, 1996). Samples of soil from beneath the pit sludge showed concentration levels below 1 percent. (Duke Engineering Services, Inc., 2001a). EM surveys indicated that saline water lies 3 to 6 ft beneath the surface around the perimeter of the site in a sand layer. The base of the saltwater appears to be at a depth of about 30 ft, where the sand is underlain by red clay (Kaiser and others, 1996).

Initial recommendations for clean up included monitoring, elimination of high-salt wastes in the pits, and natural dilution of saline groundwater. The plugged saltwater disposal well and oil well were not considered sources of documented groundwater salinity. Offsite sources of elevated salinity, chloride, and barium in groundwater, however, are possible at this site. It was recommended that pit fluids be discharged under permit to surface drainage to a nearby bayou. Onsite land treatment of high-TPH waste is preferred to removal because of the expense that would be incurred because the waste volume is great. Backfilling and leveling of pits (Kaiser and others, 1996) would require a U.S. Army Corps of Engineers wetland modification permit. Additional recommendations from a later site assessment included excavation and removal of drilling fluid wastes from the pit with the highest TPH (pit A) and testing for barium in the soil beneath the pit (Duke Engineering Services, Inc., 2001a). Assessment of the site is still in progress. To date the RRC has expended approximately \$221,100 on assessment of the site.

Munson Site

The Munson site (fig. 6a) is an abandoned site near Lyons, Burleson County, Texas. It was permitted as a low chloride drilling fluid disposal site in February 1982, after a history of operating non-permitted pits for disposal of oilfield drilling wastes. The site contained five disposal pits, only three of which were permitted. Figure 6a displays the general configuration of the site; file maps and records were insufficient to accurately reconstruct dimensions and orientations of the pits. Figure 6b compares pit-water chloride between the Munson site and all sites in the study sample; chloride in the pit water is near the mean of all sites. In May of 1982 pits were inspected revealing seeping fluids. In

1986 complaints were received that a berm had eroded and fluids were escaping onto adjacent property. Approximately 50,000 bbl of drilling fluids discharged to the adjacent creek. Also in 1986 a vacuum-truck company attempted to dispose of wastes with chloride concentrations of 70, 000 mg/L. A 1994 RRC site assessment determined that the site was abandoned and that approximately 500,000 bbl were in the pits. Pits were found leaking at an undetermined rate. Assessment of the site is still in progress.

Post Oak Site

The Post Oak site (fig. 7a-c) is located 8 mi east of Giddings, Lee County, Texas. The site is a former sandstone quarry where there had been unauthorized disposal of hydrocarbon-contaminated drilling fluids (Sullivan and others, 1999). The quarry pit had an areal extent of approximately 2.3 acres (125,000 ft²). The site contains an estimated 20,500-yd³ (554,500-ft³ or 98,753 bbl) of waste material, mainly drilling fluids. Two onsite monitoring wells were installed at the site as part of an assessment.

Comparisons of chloride, TPH, barium, and arsenic in sludge at the Post Oak site to all sites in the study sample are shown in figures 7d-g. Chloride concentration in one of the monitoring wells (550 mg/L) exceeded the SMCL unenforceable aesthetic guideline (250 mg/L); additional data were needed to define background concentration and establish whether the site was a source of chloride. Several other constituents exceeded regulatory guidelines. In both monitoring wells, EPA maximum contaminant levels (MCLs) for cadmium (0.005 mg/L) and chromium (0.1 mg/L) were exceeded. Cadmium ranged from 0.031 to 0.018 mg/L and chromium ranged from 0.15 to 0.32 mg/L. Lead was detected at 0.093 to 0.019 mg/L, above the EPA action levels of 0.015 mg/L. The action level is the concentration above which steps must be taken to reduce the

concentration for drinking water. Among organic constituents, only naphthalene in MW2 (0.042 mg/L) exceeded the TNRCC guideline limit for residential land use of 0.49 mg/L.

Samples of pit sludge were collected at 15 locations on a regular grid across the site; samples were not composited to allow an evaluation of spatial variation. Chloride, TPH, and lead in the waste material vary across the pit (fig. 7a-c). Mean chloride concentration (953 mg/kg; fig. 7d) is near the mean for all sites in the study sample; maximum measured chloride in sludge was about 2,500 mg/kg (fig. 7a). Mean sludge TPH concentration (903 mg/kg) was less than average (fig. 7e). An off-site background soil sample taken near the southwestern end of the pit shows a chloride concentration of 2 mg/kg and no TPH. Pit fluids had chloride levels of only 150 mg/L, well below the SMCL unenforceable aesthetic guideline for drinking water. Pit solids were determined to be appropriate for onsite land treatment.

Recommendations for site remediation included removal of the waste package from the pit for onsite land treatment. It was further recommended that a minimum of 6 additional monitoring wells be installed onsite to further evaluate potential for groundwater impact. It was estimated that waste removal and land treatment, installation of monitoring wells, and 5 years of monitoring would cost about \$246,000. Site assessment is continuing.

Red River Oilfield Services Site

The Red River Oilfield Services site (fig. 8a) is an abandoned site near Tolbert, Wilbarger County, Texas. The site was permitted as a oil reclamation site in 1986 and administratively closed in May 1992 after abandonment. The site included a 50 ft by 40 ft lined pit used for separation by skimming of oil from saltwater; and a 36 ft by 8 ft plastic-

lined, partitioned steel holding pit used for temporary storage of separated saltwater prior to transfer to steel storage tanks before final disposal. A steel tank of unreported dimensions was also at the site. Both pits were enclosed by 1.5 to 2-ft high dikes constructed from material excavated from pits to prevent inflow of storm water. Several operations-related buildings and abandoned dwellings also existed. The predominant land use in the area is agriculture. In 1993 the RRC received complaints that rain-filled pits were overflowing.

Site assessment by the RRC determined that the site contained approximately 2,000 bbl of liquid and solid waste material. Analyses of dry sludge from the pits documented oil and grease content of 46 to 73 percent and TPH of 360,000 to 450,000 mg/kg (36 to 45 percent). Specific conductance of pit fluids was 5,450 to 22,600 μ mhos/cm. Pit fluid samples also contained 1,772 to 8,169 mg/L chloride, 10 to 11 percent oil and grease, and an average of <5 mg/kg TPH. The skimming pit had a pH of 4.9 and the saltwater pit had a pH of 7.7. Sludge TPH had one of the highest average values (360,000 mg/kg) of all study samples

Site remediation included removal to a RRC-approved facility of all sludge, paraffin, tank bottom sediment, drilling mud, solids from pits and tanks, pit water and tank washwater, the liner from the skimming pit, disassembled components of the steel pit, steel tank and associated equipment, oil-stained soils, excavated soil from pit walls and bottoms, and various debris. Total State expenditure for site assessment and remediation was approximately \$24,700.

Roeling Vacuum Site

The Roeling Vacuum site (fig. 9a-c) is an abandoned site located 6 mi northeast of Liberty, Liberty County, Texas (Sullivan and others, 1998). The site consists of two washout pits, 8 small pits with average dimensions of 11-ft diameter and 4-ft depth, and a larger irregularly shaped waste disposal area measuring approximately 600 ft by 200 ft wide. The site was originally a quarry for dirt for oil-field roads. The 8 waste pits contained an estimated 950 yd³ of waste materials and the larger waste disposal cell contained an estimated 16,500 yd³.

Assessment methods had included an EM survey of the site, trenching and probing of the soil, installation of three monitoring wells and groundwater sampling, and an inventory and sampling of nearby domestic water-supply wells. Chloride concentration in onsite groundwater ranged from 140 to 710 mg/L and averaged about 400 mg/L, exceeding the SMCL unenforceable aesthetic guideline (250 mg/L) in two of the three monitoring wells. Chloride concentration in the main waste disposal area and smaller side pits (fig 9a-c) averaged 5,653 mg/kg and was as high as 42,000 mg/kg. Mean chloride concentration in soil beneath the waste in the waste disposal area was 5,773 mg/kg. Comparison of chloride, TPH, barium, and arsenic in sludge at the Roeling Vacuum site to all study samples are shown in figure 9d-g. These constituents appear at or somewhat less than the average values for all study samples. Other constituents of concern were below regulatory guidelines.

A preliminary recommendation for remediation included excavation from the waste disposal area of high-chloride wastes and adjacent soils and removal to a RRC-approved site. There is insufficient volume of clean soil on-site to completely refill pit

excavations, but partial back filling and establishment of a wetlands area would be appropriate. There also were concerns for groundwater impacts resulting from excavation of the main disposal area. It was recommended that additional monitoring wells be installed including an upgradient well to determine background concentrations.

Assessment of the site is still in progress.

Rule Tank Trucks Site

The Rule Tank Trucks site (fig. 10a) is an abandoned reclamation facility located in southeast Rule, Haskell County, Texas. The site was permitted as a facility to process produced saltwater and tank bottoms, but may have received other non-permitted drilling wastes. The site contained 13 storage tanks and a 60 yd³ cinder-block-lined pit that contained debris including oil cans and oil filters, 2 yd³ of sediment, and 18 bbl of water. A tank-truck trailer containing 35 bbl of liquid waste was also on site.

Five monitor wells were installed as part of an RRC-sponsored investigation (Duke Engineering Services, 2001b). Analyses confirmed that groundwater had not been significantly impacted (620 mg/L chloride; 1,100 mg/L TDS). TPH was 65,700 to 128,000 mg/kg in pit sludge, 135,000 to 417,000 mg/kg in tank sludge; and 10,700 mg/kg in sludge stored in the trailer tank. Lead content of sludge in one of the tanks was 690 mg/kg. Comparison of barium and arsenic in sludge at the Rule site with all study samples are shown in figure 10b-c. Mean barium and arsenic in site sludge was similar to the mean of all study samples.

Remediation consisted of removal of the hydrocarbon-contaminated wastes from tanks, the pit, and 580 yd³ of soils excavated from around the pit and tanks to the Borden County Waste Disposal Facility. The tanks were cleaned, dismantled, and recycled. The

five monitoring wells were to be plugged in March 2003. Total cost to the State for assessment and remediation was approximately \$191,800. No further remedial activities were planned for this site.

Steve's Oilfield Services

The Steve's Oilfield Services site (fig. 11) is an abandoned reclamation site near Kingsville, Kleberg County, Texas, that accepted saltwater, tank-bottom sediment, and processed drilling mud for reuse. The site had two tank-truck washout pits containing drilling fluids, and three monitoring wells that were installed during site assessment. RRC sent the facility a forfeit order in August 1993 after receiving complaints about fluids overflowing onto cultivated lands that surround the site, and reports of illegal deliveries. The site was later abandoned. During site assessment, the site was found to have 14 tanks, some of which were leaking, two 180-ft² concrete wash-out pits, 15 unlabeled drums containing unknown materials scattered about, 11 storage and 3 fracture media tanks, a building, six soil mounds, and patches of oil-stained soil.

Site assessment consisted of a technical review of the site geology, soils, and regional hydrology. Neighbors were interviewed. Analyses were performed to characterize waste disposal requirements. It was concluded that there was no contamination of soils or groundwater. Pits were found to contain several barrels of water, sediment, some hydraulic oil, and drilling-mud polymer. Mean barium concentration (4,700 mg/L) in one pit, and barium concentration averaged for all pits (3,400 mg/kg), exceeded the TCEQ risk-reduction program residential Tier 1 level of 2,800 mg/kg (TNRCC, 1999). Clean up consisted of removal of all pit contents and site equipment and hardware associated with the reclamation operation. Pits were back-filled,

leveled, and compacted. Total expenditure by the State for assessment and clean up was approximately \$196,300.

Summary of Examples

The objective of site assessment in these examples was to identify the nature, sources, and extent of constituent of concern that resulted from disposal of E&P drilling fluids, produced water and associated wastes at CCDD facilities. A comprehensive investigation requires analyses of waste material within and outside of pits, calculation of the amount of impacted materials, and evaluation of any impairment of groundwater quality. The most commonly occurring constituents of concern found in pits at CCDD sites were hydrocarbons and saltwater mixed with drilling fluids. Detection of hydrocarbon constituents most commonly used TPH analysis. In some examples, BTEX or more specific analyses have been included. Pit water with high chloride can be a source of increased salinity in soil, groundwater, and surface water. Analysis of concentrations of constituents, such as chloride and TPH, and determination of the gradient of hydraulic head in groundwater, have usually been conducted to assess water quality and the potential for migration of constituents away from a site. EM surveys have been employed where saltwater contamination is suspected.

Remediation procedures have been used to cost effectively isolate or remove impacted materials from the environment. Environmentally deleterious materials have been removed or sites have been modified to reduce selected constituent concentrations to acceptable levels. Pits have been modified or closed to eliminate physical hazards. Cleanup also eliminates off-site excursion of waste materials or pit waters. Pits and other

excavations are backfilled with clean soil and sites have been leveled and graded to direct surface runoff drainage away from excavations.

PLANS FOR THE NEXT REPORTING PERIOD

Plans for the next reporting period include (1) completing the census of CCDD sites to determine a final number for the population of abandoned CCDD sites in the study area, (2) completing summaries of well documented sites that are being used as examples for comparison to poorly documented abandoned sites, and (3) presenting a short course on regulation, assessment, and remediation of oil field exploration and production sites in Texas and Louisiana. The workshop is being presented as part of the Annual Meeting of the Gulf Coast Association of Geological Societies in Austin, Texas. Presenters will include Dr. Alan R. Dutton and Dr. Jeffrey G. Paine, Bureau of Economic Geology; Dr. Lloyd Deuel, Jr., Soil Analytical Services, Inc.; Mr. John Tintera, Railroad Commission of Texas; and Mr. Carroll Wascom, Louisiana Office of Conservation. The technology transfer workshop will cover topics including State regulations in Texas and Louisiana, assessment techniques for CCDD sites, and considerations for selection of appropriate remediation methods.

ASSESSMENT OF PROSPECTS FOR FUTURE PROGRESS

We will complete the scope of work in Spring 2003. The next semi-annual technical progress report, due in March 2003, will consist of most of the Final Technical Report. The Final Technical Report itself will be submitted no later than May 2003. The report will collate and integrate a number of previous study documents, including technical papers presented at the 2000 Ground Water Protection Council Annual Forum

and 2002 Gulf Coast Association of Geological Societies Annual Meeting, previous technical progress reports, and additional summaries of CCDD case examples.

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Table 1. CCDD sites in database that exceed EPA SMCL for chloride (250 mg/L) or USDW standard for TDS (10,000 mg/L). Percent value indicates fraction of sites for which data were available in each State.

Site	Exceeds SMCL (mg/L)	Exceeds USDW (mg/L)
Louisiana	544	-
Bateman Island	3,195	-
Big Diamond	1,274	-
Bourg	13,859	18,730
Castex	338	-
Lacassine	354	-
Lafrouche	7,289	12,953
Mar	2,389	-
Mermentau	47 percent	12 percent
New Mexico	668	-
C&C Landfarm	54,247	>54,247
CRI Halfway	29,364	>29,364
Parabo	2,972	-
TNT	100 percent	67 percent
Oklahoma	660	-
Arrow/Calumet	6,123	33,658
Blehm	14,705	30,039
Bluff	379	-
Bullard 28-3-7	535	-
Courtney/Briggett	3,395	11,310
Giles	2,631	-
Gray Farms	8,715	21,298
Guard 23-22-13	2,600	-
Highfill	366	-
Lee/Triple L	912	-
Samples	6,286	-
Southard	971	-
T&S	320	-
Triple S/Big Pasture	793	-
Webb/Femco	41 percent	17 percent
Texas	573	-
Briggs	12,715	>12,929
Manvel	330	-
Post Oak	535	-
Roeling Vacuum	80 percent	25 percent

Table 2. Oil and gas wastes exempt from RCRA hazardous waste regulation

- Produced water
- Drilling fluids and drill cuttings
- Drilling fluids and cuttings from offshore operations disposed on-shore
- Rigwash
- Well completion, treatment, and stimulation fluid
- Workover waste
- Basic sediment & water and other tank bottom sludge from storage facilities that hold product and exempt waste
- Accumulated materials such as hydrocarbons, solids, sand, and emulsion from production separators, fluid treating vessels, and production impoundments
- Pit sludge and contaminated bottoms from storage or disposal of exempt wastes
- Gas plant dehydration wastes, including glycol-based compounds, glycol filters, filter media, backwash, and molecular sieves
- Gas plant sweetening wastes for sulfur removal, including amine, amine filters, amine filter media, backwash, precipitated amine sludge, iron sponge, and hydrogen sulfide scrubber liquid and sludge
- Cooling tower blowdown
- Spent filters, filter media, and backwash
- Packing fluids
- Produced sand
- Pipe scale, hydrocarbon solids, hydrates, and other deposits removed from piping and equipment prior to transportation
- Hydrocarbon-bearing soil
- Piping wastes from gathering lines
- Wastes from subsurface gas storage and retrieval, except for the listed non-exempt waste
- Constituents removed from produced water before it is injected or otherwise disposed of
- Liquid hydrocarbons removed from the production stream but not from oil refining
- Gases removed from the production stream, such as hydrogen sulfide and carbon dioxide, and volatilized hydrocarbons
- Materials ejected from a producing well during blowdown
- Waste crude oil from primary field operations and production
- Light organics volatilized from exempt wastes in reserve pits or impoundments or production equipment
- Liquid and solid wastes generated by crude oil and tank bottom reclaimers

Table 3. Concentration limits of certain constituents of oil and gas wastes allowed in municipal solid-waste disposal landfills in Texas

Analyte	Total limit (mg/kg)	TCLP limit (mg/L)
Benzene	10	0.5
Arsenic	36	1.8
Barium	2,000	100
Cadmium	10	0.5
Chromium	100	5.0
Lead	30	1.5
Mercury	4	0.2
Selenium	20	1
Silver	100	5
TPH	1,500	-
TOX	50	-
PCBs	50	-
Chloride	3,000	-

Table 4. RCRA non-exempt oil and gas waste

- Unused fracturing fluids or acids
- Gas plant cooling tower cleaning waste
- Painting Waste
- Oil and gas service company waste, such as empty drums, drum washwater, vacuum truck washwater, sandblast media, painting waste, spent solvents, spilled chemicals, and waste acid
- Vacuum truck and drum washwater from trucks and drums transporting or containing non-exempt waste
- Used equipment lubricating oil
- Waste compressor lubrication oil
- Waste compressor oil, filters, and blowdown
- Used hydraulic fluid
- Waste solvents
- Waste in pipeline-related pits
- Caustic or acid cleaner
- Boiler cleaning waste
- Boiler refractory brick
- Boiler scrubber fluid, sludge, and ash
- Incinerator ash
- Laboratory waste
- Sanitary waste
- Pesticide waste
- Radioactive tracer waste
- Drums, insulation, and miscellaneous solids

Figure 1. Summary of environmental features and sampling results at the Albany Tank Yard site, Shackelford County, Texas. Map showing distribution of various elements of the facility, including pits and hydrocarbon contamination at the surface (a). Also shown are limits of remedial excavation of contaminated soils. Histograms show mean chloride in sludge (b), mean TPH in sludge (c), mean BTEX in sludge (d), mean barium in sludge (e), and mean arsenic in sludge (f). Histograms in b to f for all sites in the study sample; * indicates mean for site. Mean concentration for site in parentheses.

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Figure 2. Summary of environmental features and sampling results at the Briggs site, Matagorda County, Texas. Maps show distribution of chloride in groundwater (a), chloride in pit sludge (b), arsenic in pit sludge (c), and water levels (d). Histograms show mean chloride in groundwater (e), mean chloride in pit sludge (f), and mean arsenic in pit sludge (g). Histograms in e to g for all sites in the study sample; * indicates mean for site. Mean concentration for site in parentheses.

Figure 3. Summary of environmental features and sampling results at the Fox Vacuum site, Jasper County, Texas. Map of Fox Vacuum site showing distribution of pits and area of barren soil (a). Histograms show mean chloride in pit sludge (b), mean TPH in pit sludge (c), mean barium in pit sludge (d), mean BTEX in pit sludge (e), and mean barium in pit sludge (f). Histograms in b to f for all sites in the study sample; * indicates mean for site. Mean concentration for site in parentheses.

Figure 4. Summary of environmental features and sampling results at the Gober Disposal site, Wise County, Texas. Map of Gober Disposal site showing distribution of pits and natural direction of drainage (a). Histogram shows mean chloride in pit water (b). Histogram in b for all sites in the study sample; * indicates mean for site. Mean concentration for site in parentheses.

Figure 5. Summary of environmental features and sampling results at the Manvel Saltwater Disposal site, Brazoria County, Texas. Maps show distribution of chloride (a), barium (b), and benzene (c) in groundwater, and water levels (d). Histograms show mean chloride in groundwater (e) and mean TPH (f), mean BTEX (g), mean barium (h), and mean arsenic in pit sludge (i). Histograms in e to i for all sites in the study sample; * indicates mean for site. Mean concentration for site in parentheses.

Figure 6. Summary of environmental features and sampling results at the Robert Munson site, Burleson County, Texas. Map shows distribution of permitted pits (1, 2, and 3), non-permitted pits, and other site elements (a). Histogram shows mean chloride in pit water (b). Histogram in b for all sites in the study sample; * indicates mean for site. Mean concentration for site in parentheses.

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Figure 7. Summary of environmental features and sampling results at the Post Oak site, Lee County, Texas. Maps show distribution of chloride in pit sludge (a), TPH in pit sludge (b), and lead in pit sludge (c). Histograms show mean chloride in pit sludge (d), mean TPH in pit sludge (e), mean barium in pit sludge (f), and mean arsenic in pit sludge (g). Histograms in d to g for all sites in the study sample; * indicates mean for Post Oak site. Mean concentration for site in parentheses.

Figure 8. Summary of environmental features and sampling results at the Red River Oilfield Services site, Wilbarger County, Texas. Map shows distribution of pits and other site elements (a). Histograms show mean TPH in pit water (b) and mean TPH in sludge (c). Histogram in b and c for all sites in the study sample; * indicates mean for site. Mean concentration for site in parentheses.

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Figure 9. Summary of environmental features and sampling results at the Roeling Vacuum site, Liberty County, Texas. Maps show distribution of pits, sample locations, and other site elements (a), hydraulic head (b), and chloride in groundwater (c). Histograms show mean chloride in pit sludge (d), mean TPH in pit sludge (e), mean barium in pit sludge (f), mean arsenic in pit sludge (g). Histogram in d to g for all sites in the study sample; * indicates mean for site. Mean concentration for site in parentheses.

Figure 10. Summary of environmental features and sampling results at the Rule Tank Trucks site, Haskell County, Texas. Map shows distribution of pits, oil-contaminated surface areas, water levels, and other site elements (a) Histograms show mean barium in pit sludge (b) and mean arsenic in sludge (c). Histogram in b and c for all sites in the study sample; * indicates mean for site. Mean concentration for site in parentheses.

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Figure 11. Summary of environmental features and sampling results at the Steve's Oilfield Services site, Kleberg County, Texas. Maps show distribution of specific conductance in groundwater (a) and hydraulic head (b). Histograms show mean TPH in sludge (c); mean barium in sludge (d), and mean arsenic in sludge (e). Histograms in c to e for all sites in the study sample; * indicates mean for site. Mean concentration for site in parentheses.