WILSON CREEK

LANDFARM OPERATING PROCEDURES MANUAL

PREPARED FOR:
Chevron USA, Inc.

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DATE PREPARED:
October 2012

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I. Manual Objectives

This Manual was developed to ensure compliance with all regulatory requirements, permit conditions, and applicable laws and regulations governing the operation of Centralized Exploration and Production Waste Management Facilities, as defined by the rules promulgated by the Colorado Oil and Gas Conservation Commission (COGCC).

In addition to compliance requirements, this manual outlines “Best Practices” as guidelines to be followed by a prudent operator to maintain the highest standards of environmental stewardship. With changes in technology and increased operating experience, Chevron reserves the right to improve, optimize, and streamline ‘Best Practice’ recommendations when and where appropriate. Any significant changes or amendments to these Operating Procedures will be communicated to the COGCC for review and approval.

II. Introduction

This document has been prepared to provide guidance to Chevron for the day-to-day operations of the Wilson Creek Landfarm, a centralized Exploration and Production (E&P) waste treatment facility primarily regulated by the 900 series rules of the Colorado Oil and Gas Conservation Commission (COGCC) under the provisions of §34-60-103(4.5) of the Colorado Revised Statutes (C.R.S.). The material to be treated on the landfarm are E&P wastes exempt from hazardous regulation under Subtitle C of the Resource and Recovery Act (RCRA) of 1976. The guidance provided consists of regulatory requirements and recommended best practices. Regulatory requirements are specifically noted **(REG. REQ.)** in the text. All other guidelines and recommendations are ‘best practices’, subject to modification and improvement at the discretion of the Operator.

A. Site Description

The Wilson Creek Field is located in various sections of Townships 2 and 3 North, Range 94 West, of the 6th Principle Meridian in Rio Blanco County, Colorado. Figures 1 and 2 contain additional site location information. The town of Meeker, Colorado, which lies approximately 11 miles south of the facility, is the nearest population center. The Wilson Creek Field can be reached from Meeker by traveling approximately 0.5 miles west on State Highway 64, then traveling approximately 7 miles north of County Road 7, and finally following County Road 9 approximately 7 miles to the facility.

The Wilson Creek Field is an onshore production facility, owned and operated by Chevron. The Wilson Creek Field is located in rugged mountainous terrain consisting of steep canyon walls and deep gorges. Vehicular travel is restricted to roadways and foot travel off roadways is difficult. The Landfarm is located in the NE NW Qtr-Qtr, Section 35, T3N, R94W, Sixth P.M. (Figure 2) on a level area adjacent to a lease road. The surface drainage from the landfarm area flows northwest along natural draws for approximately 1.5 miles and eventually enters Wilson Creek. Wilson Creek drains north to the Yampa River, which flows west to its confluence with the Green River. The Green River is a major tributary to the Greater Colorado River system.

B. Landfarming Objectives

Landfarming, also known as land treatment or land application, is an above-ground remediation technology for soils that reduces concentrations of petroleum constituents through biodegradation. For Chevron's Wilson Creek Production Operations, this technology involves spreading contaminated soils, tank sludge, or other allowable waste (as described in Section III.A. below) in a thin layer on the ground surface, shallow tilling to mix with native soils, and stimulating microbial activity within the soils through aeration and the addition of fertilizers and moisture. The enhanced microbial activity results in degradation of adsorbed petroleum product constituents through microbial respiration. Chevron's goal is to remediate certain wastes (e.g., tank bottoms, pit sludge, contaminated soils) as they are produced, eliminating the need for off-site disposal of these wastes thereby reducing the environmental risks associated with transport and third-party disposal.

C. Background

The original landfarm was lined and was approximately 50' x 70'. An unlined expansion of the original landfarm was approved in July 2003 by the COGCC which enlarged the landfarm to approximately 1.36 acres. As part of the expansion approval, the COGCC directed that no 'wet' or de-watered waste was to be applied to the unlined section of the landfarm. A separate temporary unlined landfarm was established in August 2005 to accept soils from the emergency pit excavation and was expanded in Summer 2006. At about the same time, the original landfarm and its expansion were combined and the partial liner was removed. In October 2010, the COGCC approved the re-installation of an improved liner (24 mil) under a portion of the landfarm, along with three groundwater monitoring wells. The liner and the three groundwater monitoring wells were installed during the summer of 2011 as shown in Figure 5.

III. General Operating Guidelines

A. Allowable Wastes – (REG. REQ.)

Wastes allowed on the Landfarm include all wastes generated by and associated with **Chevron's primary field operations in the Wilson Creek Field**. These wastes are defined by §304-60-103(4.5) C.R.S. as wastes exempt from regulation as hazardous under Subtitle C of the Resource Conservation and Recovery Act (RCRA) of 1976, as amended.

Allowable wastes include:

- Tank sludge
- Pit reclamation wastes
- Spent SulfaTreat catalyst
- Hydrovac mud (mud sucked from various production clean up operations at Tank Batteries and other locations)
- Soil contaminated by spills – Care should be exercised in landfarming soils contaminated by produced water. The high concentrations of salts in these soils tend to inhibit microbial activity and increase the length of time required to remediate hydrocarbon wastes.

- Any other waste directly attributable to, and characteristic of, primary oil production activities. As noted in the bullet above, some wastes 'allowable' are not ideally suited for landfarm treatment. In general, caution should be exercised when treating wastes high in inorganic contaminants (salts and metals) and low in oil content.

Wastes NOT allowed on the landfarm include, but are not limited to:

- Wastes contaminated by refined or processed materials, such as motor oil, lube oils, greases, or solvents.
- Wastes generated by anyone other than the operators of the Wilson Creek Field.
- Wastes generated by the mechanic shop, auto shop, laboratory, or any other ancillary service provided in the field.
- Aerosol cans, light bulbs, batteries, coaxial cable, orphaned workstations, construction wastes, or any other waste not unique to an upstream oil producer and not qualifying as a waste exempt from hazardous regulation under Subtitle C of RCRA.

B. Waste Preparation and Application

Prior to transport to the landfarm, tank and pit sludge should be de-watered as much as possible. Wastes with high water content pose both technical and pragmatic challenges to landfarm operations. The technical challenge stems from the fact that water associated with these wastes usually contains high concentrations of salts, inhibiting the effectiveness of the microbial degradation. The pragmatic challenge results from the difficultly of operating heavy equipment in an excessively wet muck.

As a condition of the expansion, no 'wet' type wastes are to be applied to any part of the unlined portion of the landfarm (**REG. REQ. per COGCC permit condition, COGCC Communication, July 2, 2003).** Any waste that exhibits a liquid character will be either de-watered or applied to a lined area within the landfarm.

De-watered wastes are typically transported to the landfarm by end-dump trucks or other earth moving equipment and placed on a specified landfarm area. The volume and type of each waste is recorded in a Recordkeeping Log (Appendix A) kept at the site. Records of the wastes applied to the landfarm are kept at the Wilson Creek Main Office.

Optimum oil loading for maximum remediation has been shown in the lab to occur at an oil concentration of about $10\%_{wt}$ oil in the soil, with a maximum loading of about $20\%_{wt}$. Approximately 860 yd^3 of tank sludges (assuming approximately $45\%_{vol}$ oil) can be applied to each acre of landfarm to reach the optimum level of loading. Based on operational experience, it is unlikely that enough waste can be applied to reach the optimum levels of oil loading. Application of 860 yd^3 of material evenly on one acre would raise the level of the landfarm over 6 inches. Depending on the nature of the waste, working that much sludge-like material into such a small area is difficult with typical earth moving equipment.

A more reasonable loading guideline is to estimate the thickness of sludge that can be reasonably worked into the soil, given available equipment, landfarm soil conditions, and physical characteristics of the waste applied. A typical estimate might be 2 or 3 inches of sludge over the available surface area. For two inches, a one acre area could accommodate 268 yd^3. For three inches, the volume would be 404 yd^3.

C. Tilling and Plowing

The waste will be thin-spread and tilled to a depth of 9-12 inches. Tilling serves two purposes – 1.) reducing VOC emissions and, 2.) aerating the soil. To ensure adequate oxygen exposure, the waste should not be tilled any deeper than 9-12 inches during the waste application processes. After the initial tilling, the landfarm should be periodically shallow tilled during the active months (approximately April – October). Shallow tilling is recommended at least once a month. Additional tilling will enhance bioremediation.

Over time some hydrocarbon may leach into slightly deeper soil horizons of the landfarm. Periodic deep tilling, plowing, or ripping to a depth of 18 – 24 inches is recommended for the unlined portion of the landfarm to bring any leached hydrocarbon to the surface to facilitate thorough bioremediation. The frequency and timing of this deeper tilling is best determined by the Operator, based on field experience and known loading on the landfarm. All other operating conditions being equal, a prudent operating practice would be to deep plow the unlined portion of the landfarm annually.

Because of the risk of penetrating the liner, deep tilling of the lined portion of the landfarm is not recommended unless soil core samples indicate an unacceptably high concentration of hydrocarbon is accumulating in the deeper horizons. If deep tilling is deemed necessary, extreme caution should be exercised to control the depth of the till and prevent damage to the liner.

D. Irrigation

Keeping the landfarm soil moisture between 5% – 20% is important to effective bioremediation. Soil moisture levels higher than 20% displace oxygen and severely diminish degradation rates. Soil moisture levels below 5% will limit microbial degradation, but less severely than 20+% levels. If normal precipitation is insufficient to maintain soil moisture above 5%, supplemental fresh water should be applied to the landfarm via water truck, or other convenient method. Because of the high altitude and generally low relative humidity, soil moisture should be gauged often and fresh water applied as appropriate. Fresh water will also be used for dust control as appropriate.

E. Run-on / Run-off

Run on and run-off water will be managed through a system of diversion berms and catchment ponds, as well as application of Best Management Practices described in the field-wide Storm Water Management Plan. Storm water management facilities should be adequate to contain a 100-year, 24-hour precipitation event, but should also be designed to account for spring run-off. Based on the NOAA data (NOAA Atlas 2, Volume III, Figure 31), a 100-year / 24-

hour storm event in Wilson Creek will produce 2.8" of precipitation with an estimated 1.6" absorbed by the soil and 1.2" shed through run-off.

Run-on risks are primarily mitigated by diversionary structures. Run-off risks are managed by a series of containment berms within the landfarm perimeter.

As part of routine operating practice, all potential areas of run-off accumulation are inspected periodically. If any off-plot sheen or contamination is noted, the procedures established in the Wilson Creek Spill Prevention Control and Countermeasure (SPCC) Plan will be invoked.

F. Fertilization

As with all living things, the microbes that catalyze the degradation of hydrocarbon require a certain amount of micronutrients. Paramount among these are nitrogen and phosphorus. If the soil is deficient in these nutrients, soil supplements should be administered. Recommended nutrient levels are:

- Nitrogen (soluble) – 50 – 200 ppm
- Phosphorus - > 5 ppm

These soil amendments can be applied as chemical or organic supplements, based on cost and availability. If waste loading is expected to be light, It is recommended that the Operator test nutrient levels at least annually and exercise their best conservative judgment on the amount and timing of fertilizer application. If too little fertilizer is added the rate of bioremediation will be slower than optimum, however too much fertilizer can have toxic effects on the microbes. Therefore, under-fertilization is preferable to over-fertilization.

If waste loading is expected to be high and high efficiency bioremediation is desired for a shorter cycle time, then a more rigorous nutrient testing and soil amendment program is recommended. Periodic soil analysis for soluble nitrogen (ammonia nitrogen and nitrate nitrogen), and available phosphorus should be conducted and the results used to determine the amount of chemical fertilizer to be used. Chemical fertilizers (rather than manure) are appropriate for highest efficiency so that quantities of nutrients added to the soil can be controlled more precisely. To estimate the amount of chemical fertilizer to be added, a Nutrient Addition Worksheet has been attached as Table 1a, and an example calculation attached as Table 1b. An excel worksheet with these calculations, *Landfarm Nutrient Calcs.xls*, is being provided with this documentation.

G. Soil Removal (REG. REQ.)

To ensure an 'evergreen' facility, the final phase in landfarm operation is unloading. Without an outlet for the accumulated soil, two factors will limit the life of the landfarm – soil level and metals accumulation. Since there are non-hydrocarbon solids in the waste, the topographic surface of the landfarm will rise in spite of the hydrocarbon degradation processes. And since a small fraction of these solids are metals, the concentration of metals will also increase over time. To prevent either of these factors from limiting the life of the landfarm, reuse and recycling of remediated soils will be conducted according to the provisions of this written management plan per COGCC Rule 907 a.(3).

1. Remediation Thresholds by Rule

Removing soil from the landfarm and re-using or recycling the soil requires that the soil meet the closure requirements set out in COGCC Rules 909, 910, and Table 910-1 (Series 900 rules are attached as Appendix B). Table 2 (page 21, taken from COGCC Table 910-1) summarizes the applicable thresholds for closure.

2. Alternative Remediation Thresholds, Background Concentrations

A footnote in Table 910-1 states, *"Consideration shall be given to background concentration levels in native soils and ground water."* On December 9, 2009, the COGCC published a clarification to that footnote on their webpage stating, *"…an operator need not meet a concentration level specified in Table 910-1 if the operator can demonstrate to the COGCC's satisfaction that the Table 910-1 level is exceeded by the background level in the native soils…"*.

In cases where background soil concentrations at the Wilson Creek facility exceed the COGCC Table 910-1 thresholds (e.g., arsenic), Chevron will work with the COGCC to determine alternative thresholds on a case-by-case basis following the procedures, rules, and guidance provided by the COGCC.

3. Agency Approval

Getting COGCC approval to remove soil from the landfarm is a two-step process –

- Submit a written management plan to the Director for approval, per the requirements of Rule 907 a. (3). This plan shall describe the proposed use of the waste, method of waste treatment, product quality assurance, and shall include a copy of any certification or authorization that may be required by other laws. The written management plan may incorporate by reference the relevant sections of this Operating Procedures Manual as well as specific details of each beneficial use instance requested on COGCC's Form 27 (Remediation Workplan).
- Demonstrate compliance with the COGCC Concentration Levels listed in Table 2 or alternative remediation threshold (see Section III.G.2., above) approved by the COGCC.

4. Beneficial Use of Remediated Soils

Once the soil in a landfarm cell meets the regulatory or the approved alternative closure requirements, the surface soil from that cell can be removed from the landfarm and used for one of the following purposes (contingent on COGCC approval of Form 27 request):

- Fill dirt for construction sites.
- Fill dirt for pits closed in accordance with COGCC 900 Series rules
- Construction of containment berms, dikes, or diversionary structures to control spills and / or storm water run-off.
- Road spread for lease roads within the Unit.
- Stockpiles reserved for one of the above listed uses.
- Any other use *only with prior approval by the COGCC, submitted on a Sundry Notice, Form 4.* **(REG. REQ.)**

Whenever soil is removed from the landfarm, documentation should be developed and maintained. That documentation should include:

- Soil analytical results demonstrating compliance with the COGCC closure limits prior to soil removal (see Section IV. E).
- Date of soil removal.
- Volume of soil removed and approximate depth of soil layer removed.
- Beneficial use (as outlined above), including location of site soil is removed to.

If the soil is stockpiled for future beneficial use, then a log of the volumes, uses, and locations of the stockpiled soil should be kept for the life of the facility.

H. Site Security

Access to the landfarm is restricted by a fence and gates at the road entrances. When the landfarm is unmanned, the gates shall be locked and any landfarm activity must be approved through the Unit Environmental and Safety Representative, the Operations Supervisor, or other person specifically designated by the Operations Supervisor.

(REG. REQ.) The landfarm site will be maintained with a perimeter fire lane at least ten (10) feet in width and an additional ten (10) feet will be maintained as a buffer zone.

Normal operating hours will match the scheduled work shift(s) of the designated Operations Personnel and typically be 7 AM to 5 PM weekdays. However, due to operating needs and project schedules, those hours may vary on an as-needed basis.

I. Noise and Odor Mitigation

Because of the size and remote location of the landfarm, noise mitigation is unnecessary except in the application of personal protective equipment (hearing protection) for personnel operating equipment on the landfarm.

Odors will be mitigated by the tilling and irrigation activities described above.

J. Inspections and Maintenance

Chevron has assigned one of the Operations Personnel as the Landfarm Field Manager. That person is responsible for managing the day-to-day operations of the landfarm is responsible for periodic inspections and maintenance of equipment. Inspections will include all aspects of landfarm operation as described in this manual. Routine and special maintenance will be performed as required.

K. Emergency Response

Emergency response procedures for the Wilson Creek Facility (including the landfarm) are fully detailed in the Facility's Emergency Response and SPCC plans.

L. Winter Operation

During winter months when the soil is snow covered and/or frozen, any waste material generated for landfarm remediation will be stockpiled in the adjacent staging area.

M. Closure

A Final Closure Plan, based on the following preliminary closure plan should be submitted to the Director of the COGCC at least sixty (60) days prior to actual closure. See COGCC Rule 908(g)(2) for specifics.

The Landfarm Facility, less than two (2) acres in extent, is sited in a remote area at NE¼NW¼, Section 35, T3N, R94W, 6th PM. The closure plan consists of three phases:

- Final Remediation
- Equipment Decommissioning
- Site Reclamation

Each of the phases is described in detail below. The primary assumptions in developing this Closure Plan are:

- Where appropriate, Chevron will conduct the required soil sampling and obtain COGCC approval for alternative remediation thresholds (e.g. arsenic) based on background soil concentrations as described in Section III.H.2 above.
- There will be no groundwater impacts – currently there are no indications of groundwater impacts in the vicinity of the landfarm.

1. Final Remediation

After the final application of E&P waste on the landfarm, it is estimated that it will take five (5) years to remediate the Total Petroleum Hydrocarbons (TPH) to meet the COGCC Standard of 500 mg/kg. The current COGCC standards for soil are found in Table 2 (page 21).

During the five-year remediation span, quarterly soil sampling is recommended to provide the data necessary to optimize the operational parameters (irrigation, fertilization, soil tilling) to maximize the degradation rate. The sampling should be conducted according to the Annual Sampling Protocol contained in Section IV (page 12). Normal operating costs would also be incurred during that 5-year period and would include, but not be limited to:

- Irrigation
- Fertilization
- Soil manipulation
- Storm water management
- Routine patrol, security, and maintenance

After the quarterly sampling results indicate the landfarm meets the COGCC standards for closure, one rigorous sampling event will be conducted to ensure the data are representative and unbiased. This final sampling event will be conducted in compliance with the ASTM Guidance Documents (Appendix D):

- ASTM D6009 – Standard Guide for Sampling Waste Piles, and
- ASTM D6044 – Standard Guide for Representative Sampling for Management of Waste and Contaminated Media

Only after the results of the sampling event conducted according to the ASTM Standards confirm compliance with the COGCC Standards will Decommissioning and Site Reclamation activities commence.

2. Equipment Decommissioning

Certain equipment will need to be decommissioned and either moved to surplus equipment or appropriately disposed of. The on-site equipment includes:

- Miscellaneous surface equipment
- Fence

3. Site Reclamation

Final site reclamation will be similar to general construction project reclamation and will include:

- Obtaining a Stormwater Construction Permit and subsequent stormwater management activities
- Removal of excess soil for beneficial use
- Final contouring of entire site consistent with natural slopes and drainages
- Re-vegetation activities, including seeding (BLM approved seed mix) and erosion control structures
- Final regulatory clearance activities with the COGCC, Rio Blanco County, and other applicable agencies.

Once the regulatory thresholds have been achieved and all appropriate agency approvals have been obtained, the site is considered closed.

IV. Sampling, Monitoring, Recordkeeping, and Reporting

A. Waste Sampling

(REG. REQ.) COGCC requires that for each type of waste to be treated a characteristic waste profile shall be completed. Waste profiles have been completed for tank bottoms, oily dirt, and Sulfa Treat waste – the three most common types of waste applied to the landfarm, so additional profiling of these routine wastes is not required, unless there is a reasonable chance that the sludge being applied differs significantly from the existing profiles.

If an allowable waste that differs significantly in chemical or physical properties is applied to the landfarm, then a waste profile shall be generated for that waste. The profile should include, as a minimum:

- An evaluation of oil, water, and solids fractions,
- A metals analysis (see Table 2, page 21), and
- An analysis of the water phase for salts and total dissolved solids (TDS)

(Best Practice) – While not required, waste profiles should be generated for routine wastes annually as a check on the variability in the wastes. These data will improve the accuracy of the tools used to predict hydrocarbon degradation and TPH content of the soil. These predictions are in turn used to efficiently manage waste application and landfarm use.

B. Surface Soil (0" – 9", Biodegradation Zone)

As a best practice annual surface soil sampling and analyses should be conducted to monitor oil content, conductivity, pH, moisture, and nutrients (see Section III.E., Fertilization). These data are necessary for the efficient management of waste application, irrigation, and fertilization. The soil should be analyzed for:

- RCRA metals (As, Ba, Cd, Cr, Pb, Se, Ag, Hg – EPA 6010 / 7000)
- Total Petroleum Hydrocarbons (TPH – 8015)
- pH
- Salinity (Sodium Adsorption Ratio)

Three (3) soil samples from randomly selected locations should be composited into a single sample for analysis. Random locations should be selected using a grid system and random number generator.

C. Subsurface Soil (> 3', Unsaturated Zone)

Periodic sampling of soil at depths greater than 3 feet is recommended to monitor the extent and depth of any potential hydrocarbon migration. If migration of hydrocarbons is detected, annual 'deep' plowing is recommended to bring leached hydrocarbons to the surface.

Three (3) soil samples from randomly selected locations should be composited into a single sample for analysis. Random locations should be selected using a grid system and random number generator.

D. Soil Sampling for Soil Removal / Beneficial Use

Once a landfarm section is targeted for soil removal, certain procedures need to be employed to ensure compliance with all COGCC thresholds. Those procedures are:

- Use the soil sampling procedures outlined in Section IV.B. of this document to establish the soil contaminant levels in the area of interest. Use three (3) composited samples for each area from randomly selected locations using a grid system and random number generator.
- Estimate the total volume of soil to be removed based on surface area of area and depth of removal.
- Identify the area to be used for soil beneficial use (e.g., excavation backfill, pit remediation, post-construction contouring, berming material, etc.).
- Use a mixing calculation to estimate the final 'in-place' concentrations of all regulated contaminants, considering:
  - Landfarm soil volumes
  - Landfarm soil contaminant concentrations
  - Estimated native soil volumes used to mix with the landfarm soil volumes
  - Native soil background concentrations of regulated contaminants

- The estimated final 'in-place' contaminant concentrations should not exceed COGCC Table 910-1 thresholds (Table 2, page 21) OR the COGCC approved alternative remediation thresholds (Section III.G.2). The assumptions, analytic data, and calculations should accompany the Form 27 request for approval submitted to the COGCC.

Additional guidance on sampling waste piles and representative sampling of waste and contaminated media is provided in Appendix D – ASTM Guidance Documents.

E. Groundwater Sampling

In October 2011, one upgradient and two downgradient groundwater monitoring wells were installed as shown in Figure 5a. Samples from each well will be collected at least annually and analyzed by the latest EPA SW 846 methods where applicable. Parameters to be analyzed (per COGCC Rule 908b. (9) A.) will include:

- Chlorides
- Sulfates
- Total Dissolved Solids (TDS)
- Iron
- Manganese
- Nitrites
- Nitrates
- Selenium
- Benzene
- Toluene
- Ethylbenzene
- Xylenes
- pH
- Specific Conductance

F. Recordkeeping

The COGCC requires records of the types and volumes of waste actually applied to the landfarm, as well as a waste characterization profile (Section IV.A.) of each type of waste applied to the landfarm.

The attached recordkeeping form (Appendix A) can be used to track the required and 'best practice' data, which includes:

- Date and time of waste application
- Volume applied
- Source of the waste
- Type of waste
- Application method (type of truck) and estimated thickness of application

These records are managed and maintained by the Environmental and Safety Representative and will be available for review by personnel from the COGCC.

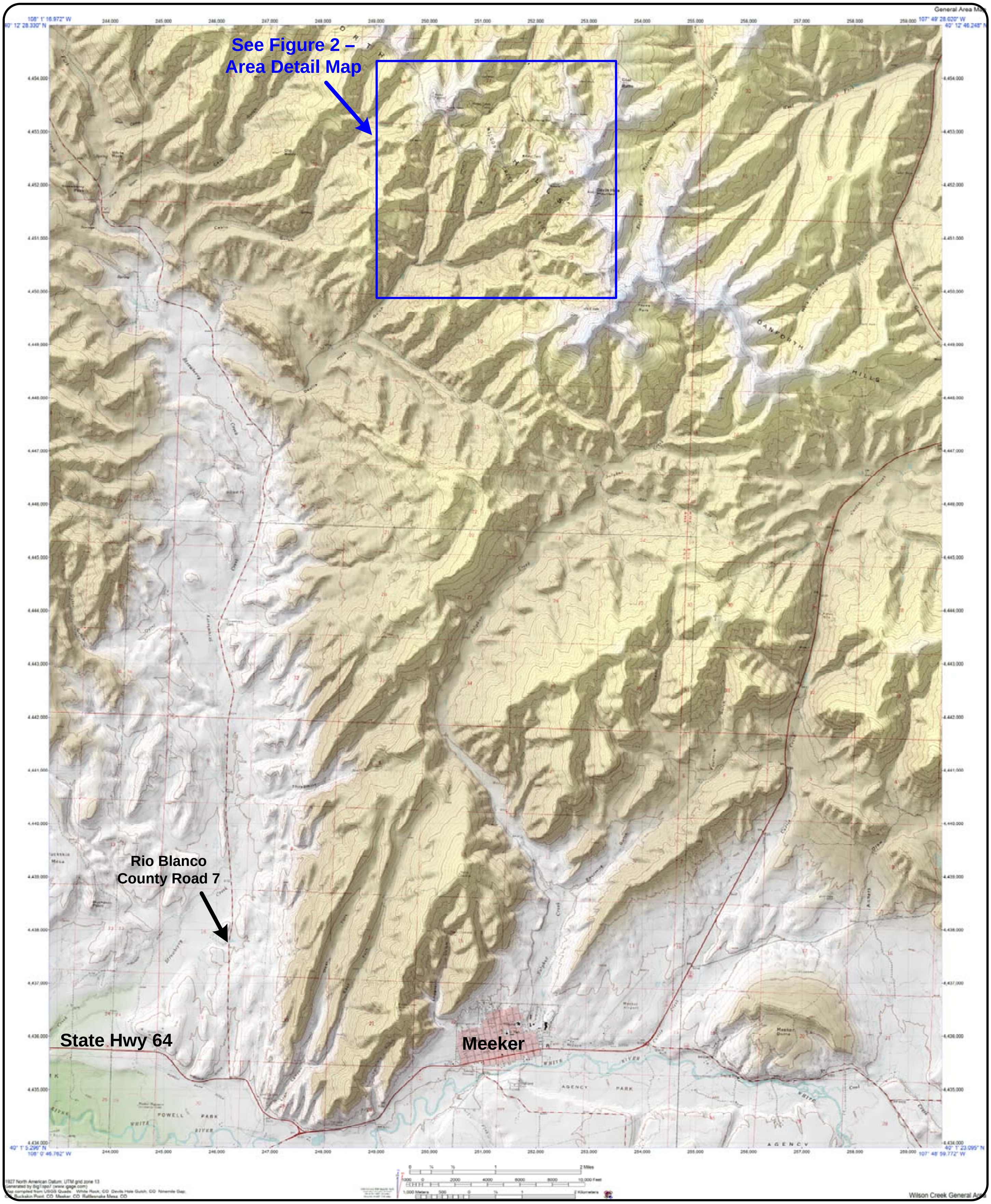
G. Reporting

(REG. REQ.) – Effective April 1, 2009, each operator of a E&P Centralized Waste Management facility is required to submit an annual report to the COGCC summarizing operations, including the types and volumes of waste actually handled at the facility (COGCC rule 908(f)). Data supplied in the attached recordkeeping format (Appendix A) can be used with a cover letter to comply with this requirement.

V. Permits and Permit Conditions

Colorado Oil and Gas Conservation Commission (COGCC)
The Wilson Creek Landfarm is classified as a centralized E&P waste treatment facility and is therefore regulated under the provisions of §34-60-103(4.5) of the Colorado Revised Statutes (C.R.S.) through the 900 series rules of the COGCC. A copy of the 900 series rules is attached as Appendix B. The soil sampling and analysis requirements are specified in these rules (as summarized above). Two other major provisions of the rules require 1.) Operators post a financial assurance bond and 2.) subsequently obtain a valid operating permit. The operators have posted a financial assurance bond (Bond No. 6049661) and the Wilson Creek Landfarm has been issued COGCC Operating Permit No. 149002.

Attached in Appendix C are copies of the original COGCC permit approval (December 1, 2000), a Sundry Notice approval for installation of a new liner (October 29, 2010), and three groundwater well permits from the Colorado Division of Water Resources (November 20, 2012).

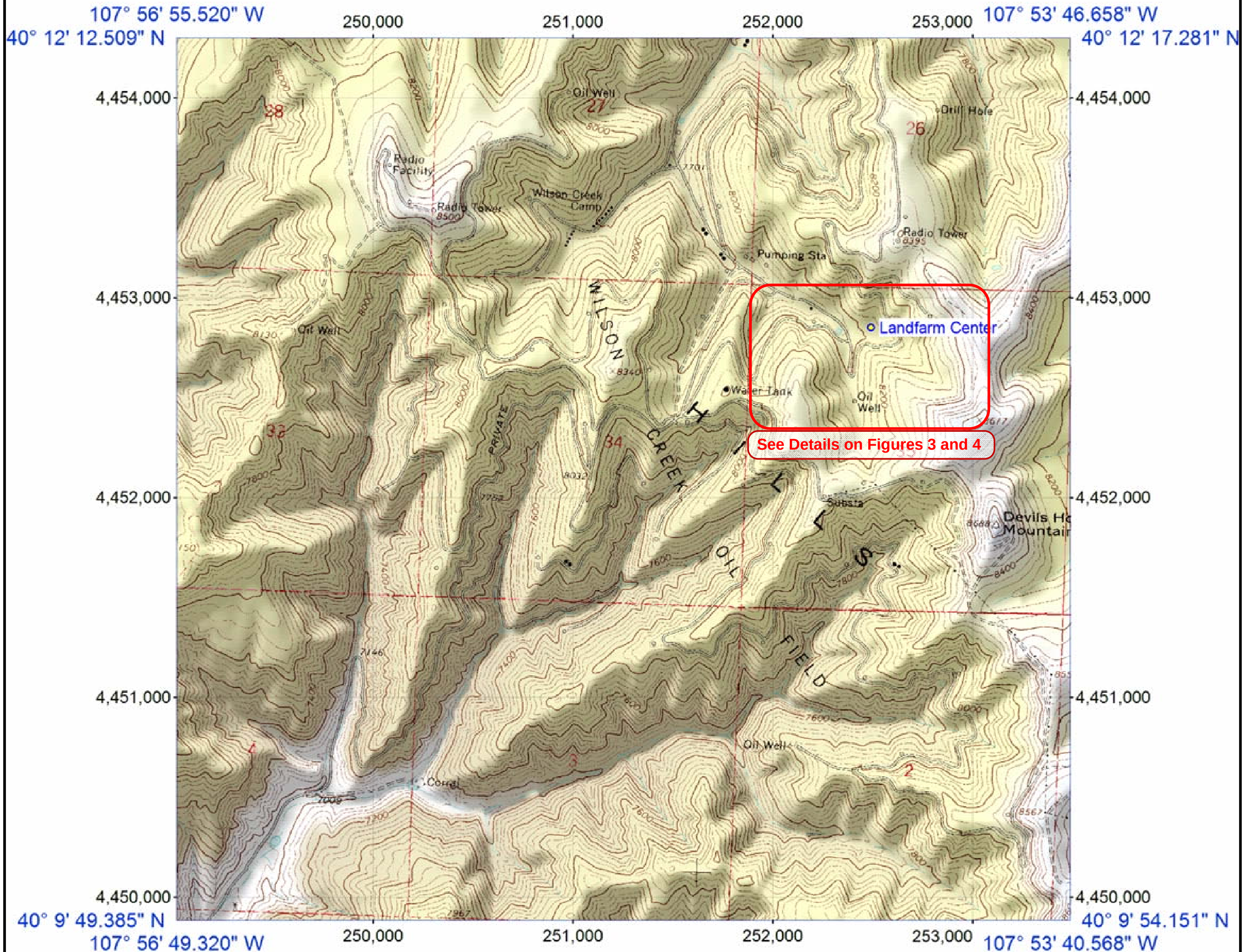


General Site Location Map Chevron USA, Inc. Wilson Creek Production Facility Rio Blanco County, Colorado	
Revision Date:	5/18/2009
Revision No.:	0
Revised By:	JYM
Approved By	JYM
Project No.:	OLS008-2084
Scale:	On map

SEVEN · SISTERS ENVIRONMENTAL

Figure 1

Detail Area Map



0 ¼ ½ Mile

0 1000 2000 Feet

0 0.5 Kilometer

TN GN MN

UTM Grid and 2009 Magnetic North Declination at Center of Sheet GN to TN 1.886° (34 mils) TN to MN 10.693° (190 mils)

1927 North American Datum; UTM grid zone 13
Generated by BigTopo7 (www.igage.com)
Map compiled from USGS Quads: Devils Hole Gulch; CO

Wilson Creek Detail Area

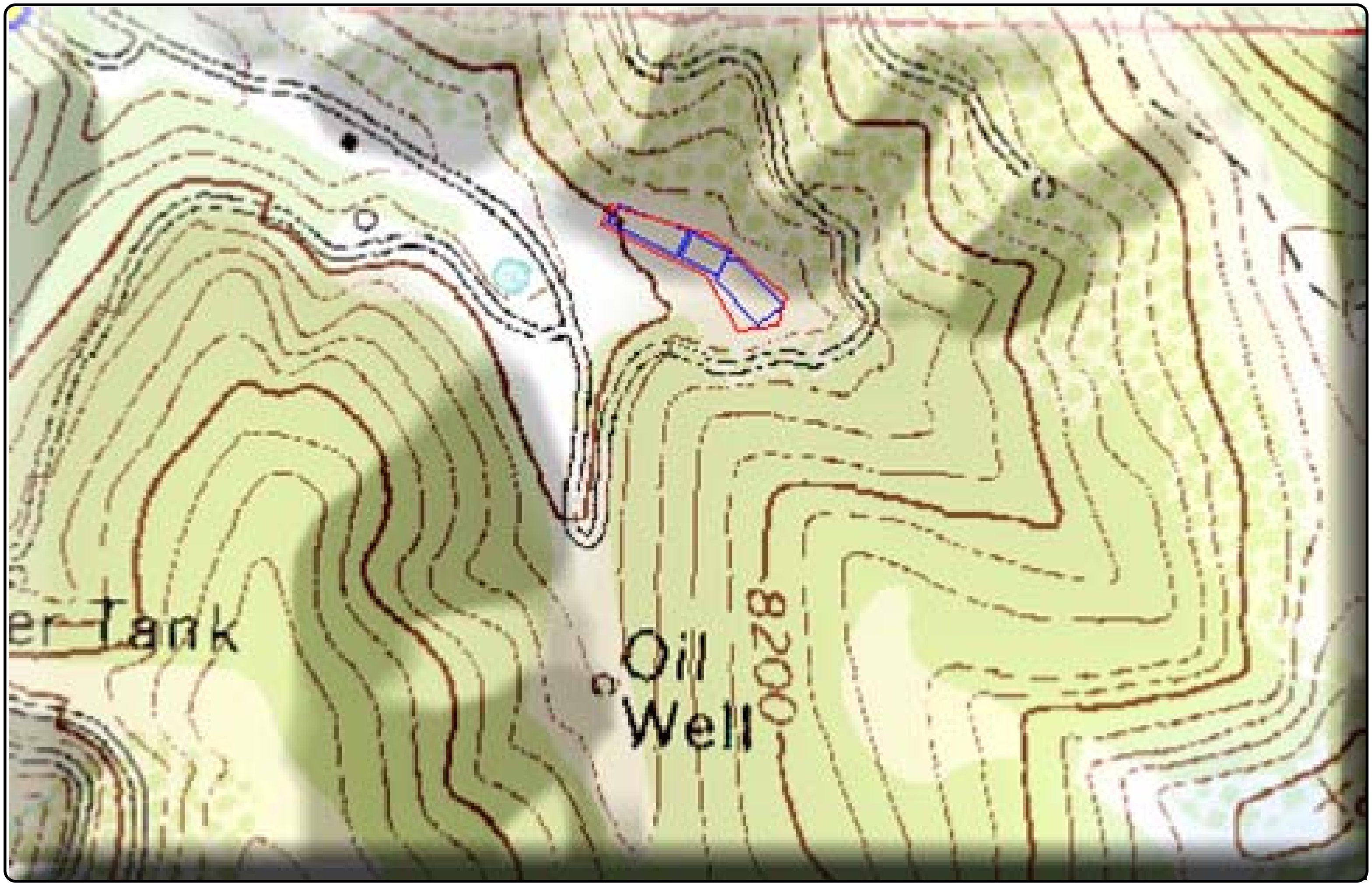
Figure 2

Area Detail Map
Chevron USA, Inc.
Wilson Creek Production Facility
Rio Blanco County, Colorado

Revision Date:	6/15/2009
Revision No.:	0
Revised By:	JYM
Approved By	JYM
Project No.:	OLS008-2084
Scale:	On map

SEVEN · SISTERS ENVIRONMENTAL

See Figures 1 and 2 for General Location reference



0 500 1000 1500 2000

Scale, feet
(approximate)

Landfarm Surveyed Boundary (transcribed from Uinta Engineering Survey, 7/20/2000)

Landfarm Cell Boundaries (approximate from Google Earth aerial photo)

Figure 3

Landfarm Boundary
Chevron USA, Inc.
Wilson Creek Production Facility
Rio Blanco County, Colorado

Revision Date:	3/05/2010
Revision No.:	0
Revised By:	JYM
Approved By	JYM
Project No.:	OLS008-2084
Scale (approx):	1" = 475'

SEVEN · SISTERS ENVIRONMENTAL

See Figures 1 and 2 for General Location reference

0 150 300 450 600

Scale, feet (approximate)

N

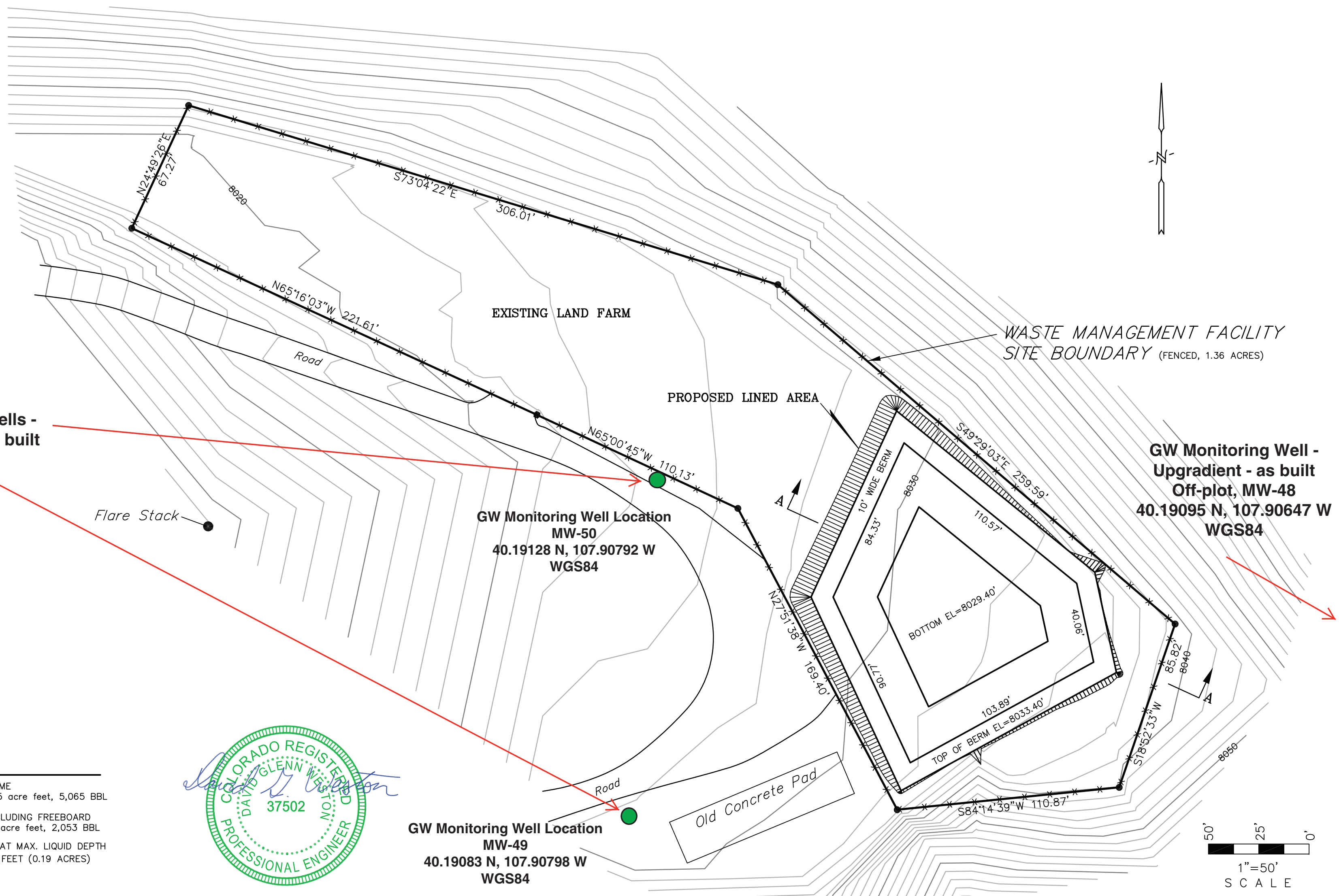
Figure 4

Landfarm Aerial
Chevron USA, Inc.
Wilson Creek Production Facility
Rio Blanco County, Colorado

Revision Date:	10/11/2012
Revision No.:	0
Revised By:	JYM
Approved By	JYM
Project No.:	OLS011-2839
Scale (approx):	1" = 130'

SEVEN · SISTERS ENVIRONMENTAL

Figure 5a



EARTHWORK APPROXIMATE VOLUMES

RAW CUT	=	778 CU. YDS.
FILL	=	705 CU. YDS.
FILL+10%	=	775 CU. YDS.

IMPORTED BEDDING/FOUNDATION
COMPACTED, IN PLACE = 430 CU. YDS.

PIT CHARACTERISTICS

INSIDE TOP 126.0' X 132.2'
INSIDE DIKE SLOPE 4:1
OUTSIDE DIKE SLOPE 2:1
DEPTH OF PIT: 4'
MAX LIQUID DEPTH: 2'
FREEBOARD DEPTH 2'

TOTAL PIT VOLUME
1,053 cyd, 0.65 acre feet, 5,065 BBL

PIT VOLUME EXCLUDING FREEBOARD
427 cyd, 0.26 acre feet, 2,053 BBL

SURFACE AREA AT MAX. LIQUID DEPTH
8,430 SQUARE FEET (0.19 ACRES)

CHEVRON
WILSON CREEK – WASTE MANAGEMENT FACILITY
PROPOSED LINED AREA
NW 1/4 NW 1/4 OF SECTION 35, T3N, R94W, 6th P.M.

SCALE: NO SCALE
DRAWING DATE: 10-7-10
REVISED:

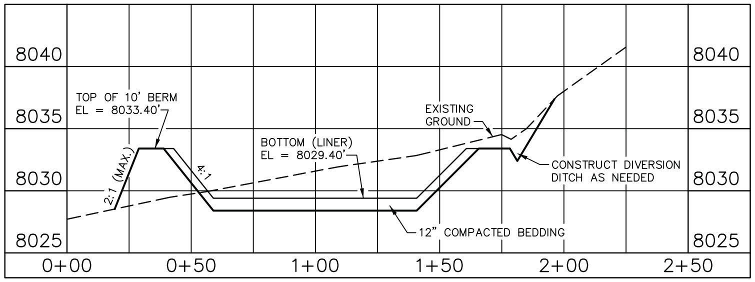
DRAWN BY: DGW
E-FILE:
PROJECT NO:
REFERENCE DRAWINGS:

UINTAH ENGINEERING & LAND SURVEYING
UINTAH ENGINEERING & LAND SURVEYING
UELS
– SINCE 1964 –

UTAH OFFICE	WYOMING OFFICE	COLORADO OFFICE	MONTANA OFFICE
85 South 200 East Vernal, UT 84078 435-789-1017	79 Winston Drive Suite 210 Rock Springs, WY 82901 307-382-3585	832 Northcrest Drive Unit B Grand Junction, CO 81506 970-263-4006	104 2nd Ave. SW Suite 300 Sidney, MT 59270 406-433-9650

SHEET NO. 1 OF 2

Figure 5b



SECTION A–A

MATERIALS SPECIFICATION

MATERIAL AND CONSTRUCTION SPECIFICATIONS:

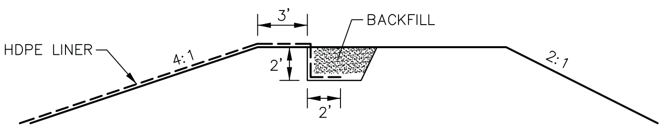
THE FOLLOWING MATERIAL LIST IS NOT ALL INCLUSIVE.
OTHER MATERIAL WILL BE NECESSARY FOR THE COMPLETION OF THE PROJECT.

PIT LINER TO BE A MINIMUM OF 24 MIL THICK HDPE OR OTHER AS APPROVED BY THE COLORADO OIL AND GAS CONSERVATION COMMISSION AND SHALL MEET THE REQUIREMENTS OF RULE 904. PIT LINERS SHALL BE INSTALLED ACCORDING TO MANUFACTURERS SPECIFICATIONS. BEDDING/FOUNDATION MATERIAL FOR THE LINER SHALL CONSIST OF 12" OF COMPACTED SOIL HAVING A HYDRAULIC CONDUCTIVITY NOT EXCEEDING 1.0 X 10^{-7} CM/SEC AFTER TESTING AND COMPACTION. THE FOUNDATION MATERIAL SELECTED SHALL BE FREE OF FRACTURED FACES CAPABLE OF PUNCTURING THE LINER MATERIAL. THE MATERIAL SHALL ALSO BE FREE OF ORGANIC AND FROZEN MATERIAL. LINER MANUFACTURER SHALL APPROVE SUBGRADE PRIOR TO INSTALLATION OF LINER.

BERM WILL BE KEYED INTO NATIVE MATERIAL. THE KEY–WAY WILL BE BACKFILLED AND COMPACTED WITH CLEAN BERM MATERIAL. NO DEBRIS WILL BE USED IN THE BERM CONSTRUCTION. NATIVE MATERIAL MAY BE USED FOR BERM CONSTRUCTION EXCEPT NO CLEAN SAND OR POROUS ROCK MAY BE USED. BERM MATERIAL MUST BE WELL GRADED.

ALL BERM MATERIAL SHALL BE COMPACTED TO AT LEAST 95% OF THE OPTIMUM OBTAINED BY AASHTO METHOD T99. THE MATERIAL MUST BE PLACED IN LIFTS NOT TO EXCEED 8" AND COMPACTION TESTS SHALL BE MADE TO VERIFY COMPACTION REQUIREMENTS. IF COMPACTION REQUIREMENTS ARE NOT MET AT 8" LIFTS, ADJUSTMENTS MUST BE MADE TO THE LIFT DEPTH (EG. 6" MAX LIFT).

– ALL APPLICABLE FEDERAL, STATE, AND LOCAL CODES WILL BE REVIEWED AND STRICTLY COMPLIED WITH.



ANCHOR TRENCH DETAIL

NO SCALE

CHEVRON
WILSON CREEK – WASTE MANAGEMENT FACILITY
PROPOSED LINED AREA
NW 1/4 NW 1/4 OF SECTION 35, T3N, R94W, 6th P.M.

SCALE: NO SCALE
DRAWING DATE: 10–7–10
REVISED:

DRAWN BY: DGW
E–FILE:
PROJECT NO:
REFERENCE DRAWINGS:

UINTAH ENGINEERING & LAND SURVEYING
– SINCE 1964 –

UTAH OFFICE	WYOMING OFFICE	COLORADO OFFICE	MONTANA OFFICE
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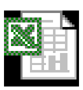
SHEET NO. 2 OF 2

TABLE 1A – NUTRIENT ADDITION WORKSHEET

Line			Units	Line			Units
1	Bulk density, soil	100.0	lb/ft3	10	Sp. Vol, bulk soil	0.01	ft3/lb
	Calculations			11	Soil weight, 1 acre x 1 ft.	2178	tons
2	Target nutrient concentration		ppm	**Nutrient content, common fertilizers - nitrogen**			
3	Current nutrient concentration		ppm	12	Urea	0.46	wt.
4	Additional nutrient required =Line 2 – Line 3		ppm	13	Ammonium nitrate	0.33	wt.
5	Fertilizer used:						
6	Required nutrient, per acre = (Line 4 / 1,000,000) x Line 11 x 2000		lbs	14	Diammonium phophate	0.18	wt.
7	Total weight fertilizer required, per acre = Line 6 / Appropriate value from Lines 12 – 19		lbs	15	Ammonium sulfate	0.21	wt.
8	Area to be fertilized		acres	**Nutrient content, common fertilizers – phosporus**			
9	Total weight of fertilizer required = Line 7 x Line 8		lbs	16	Diammonium phosphate	0.46	
				17	Monoammonium phosphate	0.48	
				18	Superphosphate	0.20	
				19	Concentrated superphosphate	0.46	

Note – a worksheet version of this spreadsheet is provided, filename - *Landfarm Nutrient Calcs.xls*.



Landfarm Nutrient
Calcs.xls

TABLE 1B – NUTRIENT ADDITION WORKSHEET, EXAMPLE

Line			Units	Line			Units
1	Bulk density, soil	100.0	lb/ft3	10	Sp. Vol, bulk soil	0.01	ft3/lb
	Calculations			11	Soil weight, 1 acre x 1 ft.	2178	tons
2	Target nutrient concentration (nitrogen)	200	ppm	**Nutrient content, common fertilizers - nitrogen**			
3	Current nutrient concentration (from analysis)	50	ppm	12	Urea	0.46	wt.
4	Additional nutrient required =Line 2 – Line 3	150	ppm	13	Ammonium nitrate	0.33	wt.
5	Fertilizer used: Urea						
6	Required nutrient, per acre = (Line 4 / 1,000,000) x Line 11 x 2000	653	lbs	14	Diammonium phophate	0.18	wt.
7	Total weight fertilizer required, per acre = Line 6 / Appropriate value from Lines 12 - 19	1,420	lbs	15	Ammonium sulfate	0.21	wt.
8	Area to be fertilized	3.2	acres	**Nutrient content, common fertilizers – phosporus**			
9	Total weight of fertilizer required = Line 7 x Line 8	4,545	lbs	16	Diammonium phosphate	0.46	
				17	Monoammonium phosphate	0.48	
				18	Superphosphate	0.20	
				19	Concentrated superphosphate	0.46	

Note – a worksheet version of this spreadsheet is provided, filename - *Landfarm Nutrient Calcs.xls*.

TABLE 2: COGCC CLOSURE LIMITS FOR REMEDIATED SOILS (FROM COGCC, RULE 910, TABLE 910-1)

(SEE NOTES ON FOLLOWING PAGE)

Contaminant of Concern	Concentrations
Organic Compounds in Soil	
TPH (total volatile and extractable petroleum hydrocarbons)	500 mg/kg
Benzene	0.17 mg/kg[2]
Toluene	85 mg/kg[2]
Ethylbenzene	100 mg/kg[2]
Xylenes (total	175 mg/kg[2]
Acenaphthene	1,000 mg/kg[2]
Anthracene	1,000 mg/kg[2]
Benzo(A)anthracene	0.22 mg/kg[2]
Benzo(B)fluoranthene	0.22 mg/kg[2]
Benzo(K)fluoranthene	2.2 mg/kg[2]
Benzo(A)pyrene	0.022 mg/kg[2]
Chrysene	22 mg/kg[2]
Dibenzo(A,H)anthracene	0.022 mg/kg[2]
Fluoranthene	1,000 mg/kg[2]
Fluorene	1,000 mg/kg[2]
Indeno(1,2,3,C,D)pyrene	0.22 mg/kg[2]
Napthalene	23 mg/kg[2]
Pyrene	1,000 mg/kg[2]
Organic Compounds in Ground Water	
Benzene	5 µg/l[3]
Toluene	560 to 1,000 µg/l[3]
Ethylbenzene	700 µg/l[3]
Xylenes (Total)	1,400 to 10,000 µg/l[3,4]
Inorganics in Soils	
Electrical Conductivity (EC)	<4 mmhos/cm or 2x background
Sodium Adsorption Ratio (SAR)	<12[5]
pH	6-9
Inorganics in Ground Water	
Total Dissolved Solids (TDS)	<1.25 x background[3]
Chlorides	<1.25 x background[3]
Sulfates	<1.25 x background[3]
Metals in Soils	
Arsenic	0.39 mg/kg[2]
Barium (LDNR True Total Barium)	15,000 mg/kg[2]
Boron (Hot Water Soluble)	2 mg/l[3]
Cadmium	70 mg/kg[3,6]
Chromium (III)	120,000 mg/kg[2]
Chromium (VI)	23 mg/kg[2,6]
Copper	3,100 mg/kg[2]
Lead (inorganic)	400 mg/kg[2]
Mercury	23 mg/kg[2]
Nickel (soluble salts)	1,600 mg/kg[2,6]
Selenium	390 mg/kg[2,6]
Silver	390 mg/kg[2]
Zinc	23,000 mg/kg[2,6]
Liquid Hydrocarbons in Soils and Ground Water	
Liquid hydrocarbons including condensate and oil	Below detection level

Notes to Table 2

COGCC recommends that the latest version of EPA SW 846 analytical methods be used where possible and that analyses of samples be performed by laboratories that maintain state or national accreditation programs.

[1] Consideration shall be given to background levels in native soils and ground water.

[2] Concentrations taken from CDPHE-HMWMD Table 1 Colorado Soil Evaluation Values (December 2007).

[3] Concentrations taken from CDPHE-WQCC Regulation 41 - The Basic Standards for Ground Water.

[4] For this range of standards, the first number in the range is a strictly health-based value, based on the WQCC's established methodology for human health-based standards. The second number in the range is a maximum contaminant level (MCL), established under the Federal Safe Drinking Water Act which has been determined to be an acceptable level of this chemical in public water supplies, taking treatability and laboratory detection limits into account. The WQCC intends that control requirements for this chemical be implemented to attain a level of ambient water quality that is at least equal to the first number in the range except as follows: 1) where ground water quality exceeds the first number in the range due to a release of contaminants that occurred prior to September 14, 2004 (regardless of the date of discovery or subsequent migration of such contaminants) clean-up levels for the entire contaminant plume shall be no more restrictive than the second number in the range or the ground water quality resulting from such release, whichever is more protective, and 2) whenever the WQCC has adopted alternative, site-specific standards for the chemical, the site-specific standards shall apply instead of these statewide standards.

[5] Analysis by USDA Agricultural Handbook 60 method (20B) with soluble cations determined by method (2). Method (20B) = estimation of exchangeable sodium percentage and exchangeable potassium percentage from soluble cations. Method (2) = saturated paste method (note: each analysis requires a unique sample of at least 500 grams). If soils are saturated, USDA Agricultural Handbook 60 with soluble cations determined by method (3A) saturation extraction method.

[6] The table value for these inorganic constituents is taken from the CDPHE-HMWMD Table 1 Colorado Soil Evaluation Values (December 2007). However, because these values are high, it is possible that site-specific geochemical conditions may exist that could allow these constituents to migrate into ground water at levels exceeding ground water standards even though the concentrations are below the table values. Therefore, when these constituents are present as contaminants, a secondary evaluation of their leachability must be performed to ensure ground water protection.

APPENDIX A – Recordkeeping Format

Wilson Creek
Landfarm Recordkeeping Format

Dumping Records										
Date of Dumping	Time of Dumping	Waste Type	Application Method	BBLS	YDS	FT^3	TONS	Source Location	Comments	Transportation Company

Wilson Creek
Landfarm Recordkeeping Format

2009 Landfarm Maintence Log									
Date of Disking	Time Disking Commenced	Disking Depth	Plowing Date	Sampling	Fertilize	Maintenance Hours	CELL Location	Comments	Chevron Representative

APPENDIX B
COGCC Series 900 Rules
(Effective April 1, 2009)

EXPLORATION & PRODUCTION (E&P) WASTE MANAGEMENT

901. INTRODUCTION

a. **General.** The rules and regulations of this series establish the permitting, construction, operating and closure requirements for pits, methods of E&P waste management, procedures for spill/release response and reporting, and sampling and analysis for remediation activities. The 900 Series rules are applicable only to E&P waste, as defined in § 34-60-103(4.5), C.R.S., or other solid waste where the Colorado Department Of Public Health And Environment has allowed remediation and oversight by the Commission.

b. **COGCC reporting forms.** The reporting required by the rules and regulations of this series shall be made on forms provided by the Director. Alternate forms may be used where equivalent information is supplied and the format has been approved by the Director.

c. **Additional requirements.** Whenever the Director has reasonable cause to believe that an operator, in the conduct of any oil or gas operation, is performing any act or practice which threatens to cause or causes a violation of Table 910-1 and with consideration of water quality standards or classifications established by the Water Quality Control Commission ("WQCC") for waters of the state, the Director may impose additional requirements, including but not limited to, sensitive area determination, sampling and analysis, remediation, monitoring, permitting and the establishment of points of compliance. Any action taken pursuant to this Rule shall comply with the provisions of Rules 324A. through D. and the 500 Series rules.

d. **Alternative compliance methods.** Operators may propose for prior approval by the Director alternative methods for determining the extent of contamination, sampling and analysis, or alternative cleanup goals using points of compliance.

e. **Sensitive area determination.** When the operator or Director has data that indicate an impact or threat of impact to ground water or surface water, the Director may require the operator to make a sensitive area determination and that determination shall be subject to the Director's approval. The sensitive area determination shall be made using appropriate geologic and hydrogeologic data to evaluate the potential for impact to ground water and surface water, such as appropriate percolation tests that demonstrate that seepage will not reach underlying ground water or waters of the State and impact current or future uses of these waters. Operators shall submit data evaluated and analysis used in the determination to the Director.

f. **Sensitive area operations.** Operations in sensitive areas shall incorporate adequate measures and controls to prevent significant adverse environmental impacts and ensure compliance with the concentration levels in Table 910-1, with consideration to WQCC standards and classifications.

902. PITS - GENERAL AND SPECIAL RULES

a. Pits used for exploration and production of oil and gas shall be constructed and operated to protect public health, safety, and welfare and the environment, including soil, waters of the state, and wildlife, from significant adverse environmental, public health, or welfare impacts from E&P waste, except as permitted by applicable laws and regulations.

b. Pits shall be constructed, monitored, and operated to provide for a minimum of two (2) feet of freeboard at all times between the top of the pit wall at its point of lowest elevation and the fluid level of the pit. A method of monitoring and maintaining freeboard shall be employed. Any unauthorized release of fluids from a pit shall be subject to the reporting requirements of Rule 906.

c. Any accumulation of oil or condensate in a pit shall be removed within twenty-four (24) hours of discovery. Operators shall use skimming, steam cleaning of exposed liners, or other safe and legal methods as necessary to maintain pits in clean condition and to control hydrocarbon odors. Only de minimis amounts of hydrocarbons may be present unless the pit is specifically permitted for oil or condensate recovery or disposal use. A Form 15 pit permit may be revoked by the Director and the Director may require that the pit be closed if an operator repeatedly allows more than de minimis amounts of oil or condensate to accumulate in a pit. This requirement is not applicable to properly permitted and properly fenced, lined, and netted skim pits that are designed, constructed, and operated to prevent impacts to wildlife, including migratory birds.

d. Where necessary to protect public health, safety and welfare or to prevent significant adverse environmental impacts resulting from access to a pit by wildlife, migratory birds, domestic animals, or members of the general public, operators shall install appropriate netting or fencing.

e. Pits used for a period of no more than three (3) years, or more than three (3) years if the Director has issued a variance, for storage, recycling, reuse, treatment, or disposal of E&P waste or fresh water, as applicable, may be permitted in accordance with Rule 903 to service multiple wells, subject to Director approval.

f. Unlined pits shall not be constructed on fill material.

g. Except as allowed under Rule 904.a, unlined pits shall not be constructed in areas where pathways for communication with ground water or surface water are likely to exist.

h. Produced water shall be treated in accordance with Rule 907 before being placed in a production pit.

i. Operators shall utilize appropriate biocide treatments to control bacterial growth and related odors as needed.

903. PIT PERMITTING/REPORTING REQUIREMENTS

a. An Earthen Pit Report/Permit, Form 15, shall be submitted to the Director for prior approval for the following pits:

(1) All production pits.

(2) Special purpose pits except those reported under Rule 903.b.(1) or Rule 903.b.(2).

(3) Drilling pits designed for use with fluids containing hydrocarbon concentrations exceeding 10,000 ppm TPH or chloride concentrations at total well depth exceeding 15,000 ppm.

(4) Multi-well pits containing produced water, drilling fluids, or completion fluids that will be recycled or reused, except where reuse consists only of moving drilling fluids from one (1) oil and gas location to another such location for reuse there.

b. An Earthen Pit Report/Permit, Form 15, shall be submitted within thirty (30) calendar days after construction for the following:

(1) Special purpose pits used in the initial phase of emergency response.

(2) Flare pits where there is no risk of condensate accumulation.

c. An Earthen Pit Report/Permit, Form 15, shall not be required for drilling pits using water-based bentonitic drilling fluids with concentrations of TPH and chloride below those referenced in Rule 903.a.(3).

d. An Earthen Pit Report/Permit, Form 15, shall be completed in accordance with the instructions in Appendix I. Failure to complete the form in full may result in delay of approval or return of form.

e. The Director shall endeavor to review any properly completed Earthen Pit Report/Permit, Form 15, within thirty (30) calendar days after receipt. In order to allow adequate time for pit permit review and approval, operators shall submit an Earthen Pit Report/Permit, Form 15, at the same time as the Application for Permit to Drill, Form 2, is submitted. The Director may condition permit approval upon compliance with additional terms, provisions, or requirements necessary to protect the waters of the state, public health, or the environment.

904. PIT LINING REQUIREMENTS AND SPECIFICATIONS

a. Pits that were constructed before May 1, 2009 on federal land, or before April 1, 2009 on other land, shall comply with the rules in effect at the time of their construction. The following pits shall be lined if they are constructed on or after May 1, 2009 on federal land, or on or after April 1, 2009 on other land:

(1) Drilling pits designed for use with fluids containing hydrocarbon concentrations exceeding 10,000 ppm TPH or chloride concentrations at total well depth exceeding 15,000 ppm.

(2) Production pits , other than skim pits, unless the operator demonstrates to the Director's satisfaction that the quality of the produced water is equivalent to or better than that of the underlying groundwater or the operator can clearly demonstrate by substantial evidence, such as by appropriate percolation tests, that seepage will not reach the underlying aquifer or waters of the state at contamination levels in excess of applicable standards. Subject to Rule 901.c, this requirement shall not apply to such pits in Washington, Yuma, Logan, Morgan, Huerfano, or Las Animas Counties constructed before May 1, 2011.

(3) Special purpose pits, except emergency pits constructed during initial emergency response to spills/releases, or flare pits where there is no risk of condensate accumulation.

(4) Skim pits.

(5) Multi-well pits used to contain produced water, drilling fluids, or completion fluids that will be recycled or reused, except where reuse consists only of moving drilling

fluids from one oil and gas location to another such location for reuse there. Subject to Rule 901.c, this requirement shall not apply to multi-well pits used to contain produced water in Washington, Yuma, Logan, Morgan, Huerfano, or Las Animas Counties constructed before May 1, 2011.

(6) Pits at centralized E&P waste management facilities and UIC facilities.

b. The following specifications shall apply to all pits that are required to be lined:

(1) Materials used in lining pits shall be of a synthetic material that is impervious, has high puncture and tear strength, has adequate elongation, and is resistant to deterioration by ultraviolet light, weathering, hydrocarbons, aqueous acids, alkali, fungi or other substances in the produced water.

(2) All pit lining systems shall be designed, constructed, installed, and maintained in accordance with the manufacturers' specifications and good engineering practices.

(3) Field seams must be installed and tested in accordance with manufacturer specifications and good engineering practices. Testing results must be maintained by the operator and provided to the Director upon request.

c. The following specifications shall also apply to pits that are required to be lined, except those at centralized E&P waste management facilities, unless an oil and gas operator demonstrates to the satisfaction of the Director that a liner system offering equivalent protection to public health, safety, and welfare, including the environment and wildlife resources, will be used:

(1) Liners shall have a minimum thickness of twenty-four (24) mils. The synthetic or fabricated liner shall cover the bottom and interior sides of the pit with the edges secured with at least a twelve (12) inch deep anchor trench around the pit perimeter. The anchor trench shall be designed to secure, and prevent slippage or destruction of, the liner materials.

(2) The foundation for the liner shall be constructed with soil having a minimum thickness of twelve (12) inches after compaction covering the entire bottom and interior sides of the pit, and shall be constructed so that the hydraulic conductivity shall not exceed 1.0×10^{-7} cm/sec after testing and compaction. Compaction and permeability test results measured in the laboratory and field must be maintained by the operator and provided to the Director upon request.

(3) As an alternative to the soil foundation described in Rule 904.c.(2), the foundation may be constructed with bedding material that exceeds a hydraulic conductivity of 1.0×10^{-7} cm/sec, if a double synthetic liner system is used; however, the bottom and sides of the pit shall be padded with soil or synthetic matting type material and shall be free of sharp rocks or other material that are capable of puncturing the liner. Each synthetic liner shall have a minimum thickness of twenty-four (24) mils.

d. The following specifications shall also apply to pits used at centralized E&P waste management facilities, unless an oil and gas operator demonstrates to the satisfaction of the Director that a liner system offering equivalent protection to public health, safety, and welfare, including the environment and wildlife resources, will be used:

(1) Liners shall have a minimum thickness of sixty (60) mils. The synthetic or fabricated liner shall cover the bottom and interior sides of the pit with the edges secured with at least a twelve (12) inch deep anchor trench around the pit perimeter. The anchor trench shall be designed to secure, and prevent slippage or destruction of, the liner materials.

(2) The foundation for the liner shall be constructed with soil having a minimum thickness of twenty-four (24) inches after compaction covering the entire bottom and interior sides of the pit, and shall be constructed so that the hydraulic conductivity shall not exceed 1.0 x 10^{-7} cm/sec after testing and compaction. Compaction and permeability test results measured in the laboratory and field must be maintained by the operator and provided to the Director upon request.

(3) As an alternative to the soil foundation described in Rule 904.d.(2), a secondary liner consisting of a geosynthetic clay liner, which is a manufactured hydraulic barrier typically consisting of bentonite clay or other very low permeability material, supported by geotextiles or geomembranes, which are held together by needling, stitching, or chemical adhesives, may be used.

e. In Sensitive Areas, the Director may require a leak detection system for the pit or other equivalent protective measures, including but not limited to, increased record-keeping requirements, monitoring systems, and underlying gravel fill sumps and lateral systems. In making such determination, the Director shall consider the surface and subsurface geology, the use and quality of potentially-affected ground water, the quality of the produced water, the hydraulic conductivity of the surrounding soils, the depth to ground water, the distance to surface water and water wells, and the type of liner.

905. CLOSURE OF PITS, AND BURIED OR PARTIALLY BURIED PRODUCED WATER VESSELS.

a. Drilling pits shall be closed in accordance with the 1000-Series Rules.

b. Pits not used exclusively for drilling operations, buried or partially buried produced water vessels, and emergency pits shall be closed in accordance with an approved Site Investigation and Remediation Workplan, Form 27. The workplan shall be submitted for prior Director approval and shall include a description of the proposed investigation and remediation activities in accordance with Rule 909. Emergency pits shall be closed and remediated as soon as the initial phase of emergency response operations are complete or process upset conditions are controlled.

(1) Operators shall ensure that soils and ground water meet the concentration levels of Table 910-1.

(2) **Pit evacuation.** Prior to backfilling and site reclamation, E&P waste shall be treated or disposed in accordance with Rule 907.

(3) Liners shall be disposed as follows:

A. **Synthetic liner disposal.** Liner material shall be removed and disposed in accordance with applicable legal requirements for solid waste disposal.

B. **Constructed soil liners.** Constructed soil liner material may be removed for treatment or disposal, or, where left in place, the material shall be ripped and mixed with native soils in a manner to alleviate compaction and prevent an impermeable barrier to infiltration and ground water flow and shall meet soil standards listed in Table 910-1.

(4) Soil beneath the low point of the pit must be sampled to verify no leakage of the managed fluids. Soil left in place shall meet the standards listed in Table 910-1.

c. **Discovery of a spill/release during closure.** When a spill/release is discovered during closure operations, operators shall report the spill/release on the Spill/Release Report, Form 19, in accordance with Rule 906. Leaking pits and buried or partially buried produced water vessels shall be closed and remediated in accordance with Rules 909 and 910.

d. **Unlined drilling pits.** Unlined drilling pits shall be closed and reclaimed in accordance with the 1000 Series rules and operators shall ensure that soils and ground water meet the concentration levels in Table 910-1.

906. SPILLS AND RELEASES

a. **General.** Spills/releases of E&P waste, including produced fluids, shall be controlled and contained immediately upon discovery to protect the environment, public health, safety, and welfare, and wildlife resources. Impacts resulting from spills/releases shall be investigated and cleaned up as soon as practicable. The Director may require additional activities to prevent or mitigate threatened or actual significant adverse environmental impacts on any air, water, soil or biological resource, or to the extent necessary to ensure compliance with the concentration levels in Table 910-1, with consideration to WQCC ground water standards and classifications.

b. **Reportable spills and reporting requirements for spills/releases.**

(1) Spills/releases of E&P waste or produced fluid exceeding five (5) barrels, including those contained within lined or unlined berms, shall be reported on COGCC Spill/Release Report, Form 19.

(2) Spills/releases which exceed twenty (20) barrels of an E&P waste shall be reported on COGCC Spill/Release Report, Form 19, and shall also be verbally reported to the Director as soon as practicable, but not more than twenty-four (24) hours after discovery.

(3) Spills/releases of any size which impact or threaten to impact any waters of the state, residence or occupied structure, livestock, or public byway shall be reported on COGCC Spill/Release Report, Form 19, and shall also be verbally reported to the Director as soon as practicable, but not more than twenty-four (24) hours, after discovery.

(4) Spills/releases of any size which impact or threaten to impact any surface water supply area shall be reported to the Director and to the Environmental Release/Incident Report Hotline (1-877-518-5608). Spills and releases that impact or threaten a surface water intake shall be verbally reported to the emergency contact for that facility immediately after discovery.

(5) For all reportable spills, operators shall submit a Spill/Release Report, Form 19, within ten (10) days after discovery. An 8 1/2 x 11 inch topographic map showing the governmental section and location of the spill shall be included. Such report shall also include information relating to initial mitigation, site investigation, and remediation. The Director may require additional information.

(6) Chemical spills and releases shall be reported in accordance with applicable state and federal laws, including the Emergency Planning and Community Right-to-Know Act, the Comprehensive Environmental Response, Compensation, and Liability Act, the Oil Pollution Act, and the Clean Water Act, as applicable.

c. **Surface owner notification and consultation.** The operator shall notify the affected surface owner or the surface owner's appointed tenant of reportable spills as soon as practicable, but not more than twenty-four (24) hours, after discovery. The operator also shall make good faith efforts to notify and consult with the affected surface owner, or the surface owner's appointed tenant, prior to commencing operations to remediate E&P waste from a spill/release in an area not being utilized for oil and gas operations.

d. **Remediation of spills/releases.** When threatened or actual significant adverse environmental impacts on any air, water, soil or other environmental resource from a spill/release exists or when necessary to ensure compliance with the concentration levels in Table 910-1, with consideration to WQCC ground water standards and classifications, the Director may require operators to submit a Site Investigation and Remediation Workplan, Form 27. Such spills/releases shall be remediated in accordance with Rules 909. and 910.

e. **Spill/release prevention.**

(1) **Secondary containment.** Secondary containment that was constructed before May 1, 2009 on federal land, or before April 1, 2009 on other land, shall comply with the rules in effect at the time of construction. Secondary containment constructed on or after May 1, 2009 on federal land, or on or after April 1, 2009 on other land shall be constructed or installed around all tanks containing oil, condensate, or produced water with greater than 3,500 milligrams per liter (mg/l) total dissolved solids (TDS) and shall be sufficient to contain the contents of the largest single tank and sufficient freeboard to contain precipitation. Secondary containment structures shall be sufficiently impervious to contain discharged material. Operators are also subject to tank and containment requirements under Rules 603. and 604. This requirement shall not apply to water tanks with a capacity of fifty (50) barrels or less.

(2) **Spill/release evaluation.** Operators shall determine the cause of a spill/release, and, to the extent practicable, shall implement measures to prevent spills/releases due to similar causes in the future. For reportable spills, operators shall submit this information to the Director on the Spill/Release Report, Form 19, within ten (10) days after discovery of the spill/release.

907. MANAGEMENT OF E&P WASTE

a. **General requirements.**

(1) **Operator obligations.** Operators shall ensure that E&P waste is properly stored, handled, transported, treated, recycled, or disposed to prevent threatened or actual significant adverse environmental impacts to air, water, soil or biological resources or to the extent necessary to ensure compliance with the concentration levels in Table 910-1, with consideration to WQCC ground water standards and classifications.

(2) E&P waste management activities shall be conducted, and facilities constructed and operated, to protect the waters of the state from significant adverse environmental impacts from E&P waste, except as permitted by applicable laws and regulations.

(3) **Reuse and recycling.** To encourage and promote waste minimization, operators may propose plans for managing E&P waste through beneficial use, reuse, and recycling by submitting a written management plan to the Director for approval on a Sundry Notice, Form 4, if applicable. Such plans shall describe, at a minimum, the type(s) of waste, the proposed use of the waste, method of waste treatment, product quality assurance, and shall include a copy of any certification or authorization that may be required by other laws and regulations. The Director may require additional information.

b. **Waste transportation.**

(1) E&P waste, when transported off-site within Colorado for treatment or disposal, shall be transported to facilities authorized by the Director or waste disposal facilities approved to receive E&P waste by the Colorado Department of Public Health and Environment. When transported to facilities outside of Colorado for treatment or disposal, E&P waste shall be transported to facilities authorized and permitted by the appropriate regulatory agency in the receiving state.

(2) **Waste generator requirements.** Generators of E&P waste that is transported off-site shall maintain, for not less than five (5) years, copies of each invoice, bill, or ticket and such other records as necessary to document the following requirements A through F:

A. The date of the transport;

B. The identity of the waste generator;

C. The identity of the waste transporter;

D. The location of the waste pickup site;

E. The type and volume of waste; and

F. The name and location of the treatment or disposal site.

Such records shall be signed by the transporter, made available for inspection by the Director during normal business hours, and copies thereof shall be furnished to the Director upon request.

c. **Produced water.**

(1) **Treatment of produced water.** Produced water shall be treated prior to placement in a production pit to prevent crude oil and condensate from entering the pit.

(2) **Produced water disposal.** Produced water may be disposed as follows:

A. Injection into a Class II well, permitted in accordance with Rule 325.;

B. Evaporation/percolation in a properly permitted pit;

C. Disposal at permitted commercial facilities;

D. Disposal by roadspreading on lease roads outside sensitive areas for produced waters with less than 3,500 mg/l TDS when authorized by the surface owner. Roadspreading of produced waters shall not impact waters of the state, shall not result in pooling or runoff, and the adjacent soils shall meet the concentration levels in Table 910-1. Flowback fluids shall not be used for dust suppression.

E. Discharging into state waters, in accordance with the Water Quality Control Act and the rules and regulations promulgated thereunder.

i. Operators shall provide the Colorado discharge permit number, latitude and longitude coordinates, in accordance with Rule 215.f, of the discharge outfall, and sources of produced water on a Source of Produced Water for Disposal, Form 26, and shall include a U.S.G.S. topographic map showing the location of the discharge outfall.

ii. Produced water discharged pursuant to this subsection (2).E. may be put to beneficial use in accordance with applicable state statutes and regulations governing the use and administration of water.

F. Evaporation in a properly lined pit at a centralized E&P waste management facility permitted in accordance with Rule 908.

(3) **Produced water reuse and recycling.** Produced water may be reused for enhanced recovery, drilling, and other approved uses in a manner consistent with existing water rights and in consideration of water quality standards and classifications established by the WQCC for waters of the state, or any point of compliance established by the Director pursuant to Rule 324D.

(4) **Mitigation.** Water produced during operation of an oil or gas well may be used to provide an alternative domestic water supply to surface owners within the oil or gas field, in accordance with all applicable laws, including, but not limited to, obtaining the necessary approvals from the WQCD for constructing a new "waterworks," as defined by Section 25-1-107(1)(X)(II)(A), C.R.S. Any produced water not so used shall be disposed of in accordance with subsection (2) or (3). Providing produced water for domestic use within the meaning of this subsection (4) shall not constitute an admission by the operator that the well is dewatering or impacting any existing water well. The water produced shall be to the benefit of the surface owner within the oil and gas field and may not be sold for profit or traded.

d. **Drilling fluids.**

(1) **Recycling and reuse.** Drilling pit contents may be recycled to another drilling pit for reuse consistent with Rule 903.

(2) **Treatment and disposal.** Drilling fluids may be treated or disposed as follows:

A. Injection into a Class II well permitted in accordance with Rule 325;

B. Disposal at a commercial solid waste disposal facility; or

C. Land treatment or land application at a centralized E&P waste management facility permitted in accordance with Rule 908.

(3) **Additional authorized disposal of water-based bentonitic drilling fluids.** Water-based bentonitic drilling fluids may be disposed as follows:

A. Drying and burial in pits on non-crop land. The resulting concentrations shall not exceed the concentration levels in Table 910-1, below; or

B. Land application as follows:

i. **Applicability.** Acceptable methods of land application include, but are not limited to, production facility construction and maintenance, and lease road maintenance.

ii. **Land application requirements.** The average thickness of water-based bentonitic drilling fluid waste applied shall be no more than three (3) inches prior to incorporation. The waste shall be applied to prevent ponding or erosion and shall be incorporated as a beneficial amendment into the native soils within ten (10) days of application. The resulting concentrations shall not exceed those in Table 910-1.

iii. **Surface owner approval.** Operators shall obtain written authorization from the surface owner prior to land application of water-based bentonitic drilling fluids.

iv. **Operator obligations.** Operators shall maintain a record of the source, the volume, and the location where the land application of the water-based bentonitic drilling fluid occurred. Upon the Director's written request, this information shall be provided within five (5) business days, in a format readily reviewable by the Director. Operators with control and authority over the wells from which the water-based bentonitic drilling fluid wastes are obtained retain responsibility for the land application operation, and shall diligently cooperate with the Director in responding to complaints regarding land application of water-based bentonitic drilling fluids.

v. **Approval.** Prior Director approval is not required for reuse of water-based bentonitic drilling fluids for land application as a soil amendment.

e. **Oily waste.** Oily waste includes those materials containing crude oil, condensate or other E&P waste, such as soil, frac sand, drilling fluids, and pit sludge that contain hydrocarbons.

(1) Oily waste may be treated or disposed as follows:

A. Disposal at a commercial solid waste disposal facility;

B. Land treatment onsite; or

C. Land treatment at a centralized E&P waste management facility permitted in accordance with Rule 908.

(2) Land treatment requirements:

A. Free oil shall be removed from the oily waste prior to land treatment.

B. Oily waste shall be spread evenly to prevent pooling, ponding, or runoff.

C. Contamination of stormwater runoff, ground water, or surface water shall be prevented.

D. Biodegradation shall be enhanced by disking, tilling, aerating, or addition of nutrients, microbes, water or other amendments, as appropriate.

E. Land-treated oily waste incorporated in place or beneficially reused shall not exceed the concentrations in Table 910-1.

F. When a threatened or significant adverse environmental impact from onsite land treatment exists, operators shall submit a Site Investigation and Remediation Workplan, Form 27, for approval by the Director. Treatment shall thereafter be completed in accordance with the workplan and Rules 909. and 910.

G. When land treatment occurs in an area not being utilized for oil and gas operations, operators shall obtain prior written surface owner approval.

f. **Other E&P Waste.** Other E&P waste such as workover fluids, tank bottoms, pigging wastes from gathering and flow lines, and natural gas gathering, processing, and storage wastes may be treated or disposed of as follows:

(1) Disposal at a commercial solid waste disposal facility;

(2) Treatment at a centralized E&P waste management facility permitted in accordance with Rule 908;

(3) Injection into a Class II injection well permitted in accordance with Rule 325; or

(4) An alternative method proposed in a waste management plan in accordance with rule 907.a.(3) and approved by the Director.

907A. MANAGEMENT OF NON-E&P WASTE

a. Certain wastes generated by oil and gas-related activities are non-E&P wastes and are not exempt from regulation as solid or hazardous wastes. These wastes need to be properly identified and disposed of in accordance with state and federal regulations.

b. Certain wastes generated by oil and gas-related activities can either be E&P wastes or non-E&P wastes depending on the circumstances of their generation.

c. The hazardous waste regulations require that a hazardous waste determination be made for any non-E&P solid waste. Hazardous wastes require storage, treatment, and disposal practices in accordance with 6 C.C.R. 1007-3. All non-hazardous/non-E&P wastes are considered solid waste which require storage, treatment, and disposal in accordance with 6 C.C.R. 1007-2.

908. CENTRALIZED E&P WASTE MANAGEMENT FACILITIES

a. **Applicability.** Operators may establish non-commercial, centralized E&P waste management facilities for the treatment, disposal, recycling or beneficial reuse of E&P waste. This rule applies only to non-commercial facilities, which means the operator does not represent itself as providing E&P waste management services to third parties, except as part of a unitized area or joint operating agreement or in response to an emergency. Centralized facilities may include components such as land treatment or land application sites, pits, and recycling equipment.

b. **Permit requirements.** Before any person shall commence construction of a centralized E&P waste management facility, such person shall file with the Director an application on Form 28 and pay a filing and service fee established by the Commission (see Appendix III), and obtain the Director's approval. The application shall contain the following:

(1) The name, address, phone and fax number of the operator, and a designated contact person.

(2) The name, address, and phone number of the surface owner of the site, if not the operator, and the written authorization of such surface owner.

(3) The legal description of the site.

(4) A general topographic, geologic, and hydrologic description of the site, including immediately adjacent land uses, a topographic map of a scale no less than 1:24,000 showing the location, and the average annual precipitation and evaporation rates at the site.

(5) **Centralized facility siting requirements.**

A. A site plan showing drainage patterns and any diversion or containment structures, and facilities such as roads, fencing, tanks, pits, buildings, and other construction details.

B. Scaled drawings of entire sections containing the proposed facility. The field measured distances from the nearer north or south and nearer east or west section lines shall be measured at ninety (90) degrees from said section lines to facility boundaries and referenced on the drawing. A survey shall be provided including a complete description of established monuments or collateral evidence found and all aliquot corners.

C. The facility shall be designed to control public access, prevent unauthorized vehicular traffic, provide for site security both during and after operating hours, and prevent illegal dumping of wastes. Appropriate measures shall also be implemented to prevent access to the centralized facility by wildlife or domestic animals.

D. Centralized facilities shall have a fire lane of at least ten (10) feet in width around the active treatment areas and within the perimeter fence. In addition, a buffer zone of at least ten (10) feet shall be maintained within the perimeter fire lane.

E. Surface water diversion structures, including, but not limited to, berms and ditches, shall be constructed to accommodate a one hundred (100) year, twenty four (24) hour event. The facility shall be designed and constructed with a run-on control system to prevent flow onto the facility during peak discharge and a run-off control system to contain the water volume from a twenty-five (25) year, twenty-four (24) hour storm.

(6) **Waste profile.** For each type of waste, the amounts to be received and managed by the facility shall be estimated on a monthly average basis. For each waste type to be treated, a characteristic waste profile shall be completed.

(7) **Facility design and engineering.** Facility design and engineering data, including plans and elevations, design basis, calculations, and process description.

A. Geologic data, including, but not limited to:

i. Type and thickness of unconsolidated soils;

ii. Type and thickness of consolidated bedrock, if applicable;

iii. Local and regional geologic structures; and

iv. Any geologic hazards that may affect the design and operation of the facility.

B. Hydrologic data, including, but not limited to:

i. Surface water features within two (2) miles;

ii. Depth to shallow ground water and major aquifers;

iii. Water wells within one (1) mile of the site boundary and well depth, depth to water, screened intervals, yields, and aquifer name;

iv. Hydrologic properties of shallow ground water and major aquifers including flow direction, flow rate, and potentiometric surface;

v. Site location in relation to the floodplain of nearby surface water features;

vi. Existing quality of shallow ground water; and

vii. An evaluation of the potential for impacts to nearby surface water and ground water.

C. Engineering data, including, but not limited to:

i. Type and quantity of material required for use as a liner, including design components;

ii. Location and depth of cut for liners;

iii. Location, dimensions, and grades of all surface water diversion structures;

iv. Location and dimensions of all surface water containment structures; and

v. Location of all proposed facility structures and access roads.

(8) **Operating plan.** An operating plan, including, but not limited to:

A. A detailed description of the method of treatment, loading rates, and application of nutrients and soil amendments;

B. Dust and moisture control;

C. Sampling;

D. Inspection and maintenance;

E. Emergency response;

F. Record-keeping;

G. Site security;

H. Hours of operation;

I. Noise and odor mitigation; and

J. Final disposition of waste. Where treated waste will be beneficially reused, a description of reuse and method of product quality assurance shall be included.

(9) **Ground water monitoring.**

A. **Water Wells.**

Water samples shall be collected from water wells known to the operator or registered with the Colorado State Engineer within a one (1) mile radius of the proposed facility and shall be analyzed to establish baseline water quality. Analytical parameters shall be selected based upon the proposed waste stream and shall include, at a minimum, all major cations and anions, total dissolved solids, iron and manganese, nutrients (nitrates, nitrites, selenium), benzene, toluene, ethylbenzene, xylenes, pH, and specific conductance. Operators shall use reasonable good faith efforts to identify and obtain access to such water wells for the purpose of collecting water samples. If access cannot be obtained, then the operator shall notify the Director of the wells for which access was not obtained and sampling of such wells by the operator shall not be required. Not conducting sampling because access to water wells cannot be obtained shall not be grounds for denial of the proposed facility.

Copies of all test results described above shall be provided to the Director and the water well owner within three (3) months of collecting the samples. Laboratory results shall also be submitted to the Director in an electronic data deliverable format.

B. **Site-specific monitoring wells.**

i. Where applicable, the Director shall require ground water monitoring to ensure compliance with the concentration levels in Table 910-1 and WQCC standards and classifications by establishing points of compliance, unless an oil and gas operator demonstrates to the satisfaction of the Director that an alternative method offering equivalent protection of public health, safety, and welfare, including the environment and wildlife resources, can be employed and provided the operator employs a dual liner with a leak detection system that provides for immediate leak detection from the uppermost liner. All monitoring well construction must be completed in accordance with the State Engineer's regulations on well construction, “Water Well Construction Rules” (2 C.C.R. 402-2).

ii. Where monitoring is required, the direction of flow, ground water gradient and quality of water shall be established by the installation of a minimum of three (3) monitor wells, including an up-gradient well and two (2) down-gradient wells that will serve as points of compliance, or other methods authorized by the Director.

(10) **Surface water monitoring.** Where applicable, the Director shall require baseline and periodic surface water monitoring to ensure compliance with WQCC surface water standards and classifications. Operators shall use reasonable good faith efforts to obtain access to such surface water for the purpose of collecting water samples. If access cannot be obtained, then the operator shall notify the Director of the surface water for which access was not obtained and sampling of such surface water by the operator shall not be required. Not conducting sampling because access to surface water cannot be obtained shall not be grounds for denial of the proposed facility.

(11) **Contingency plan.** A contingency plan that describes the emergency response operations for the facility, 24-hour contact information for the person who has authority to initiate emergency response actions, and an outline of responsibilities under the joint operating agreement regarding maintenance, closure, and monitoring of the facility.

c. **Permit approval.** The Director shall endeavor to approve or deny the properly completed permit within thirty (30) days after receipt and may condition permit approval as necessary to prevent any threatened or actual significant adverse environmental impact on air, water, soil or biological resources or to the extent necessary to ensure compliance with the concentration levels in Table 910-1, with consideration to WQCC ground water standards and classifications.

d. **Financial assurance.** The operator of a centralized E&P waste management facility shall submit for the Director's approval such financial assurance as required by Rule 704. prior to issuance of the operating permit.

e. **Facility modifications.** Throughout the life of the facility the operator shall submit proposed modifications to the facility design, operating plan, permit data, or permit conditions to the Director for prior approval.

f. **Annual permit review.** To ensure compliance with permit conditions and the 900 Series rules, the facility permit shall be subject to an annual review by the Director. To facilitate this review, the operator shall submit an annual report summarizing operations, including the types and volumes of waste actually handled at the facility. The Director may require additional information.

g. **Closure.**

(1) **Preliminary closure plan.** A general preliminary plan for closure shall be submitted with the centralized E&P waste management facility permit, Form 28. The preliminary closure plan shall include, but not be limited to:

A. A general plan for closure and reclamation of the entire facility, including a description of the activities required to decommission and remove all equipment, close and reclaim pits, dispose of or treat residual waste, collect samples as needed to verify compliance with soil and ground water standards, implement post-closure monitoring, and complete other remediation, as required.

B. An estimate of the cost to close and reclaim the entire facility and to conduct post-closure monitoring. Cost estimates shall be subject to review by the Director.

(2) **Final closure plan.** A detailed Site Investigation and Remediation Workplan, Form 27, shall be submitted at least sixty (60) days prior to closure for approval by the Director. The workplan shall include, but not be limited to, a description of the activities required to decommission and remove all equipment, close and reclaim pits, dispose of or treat residual waste, collect samples as needed to verify compliance with soil and ground water standards, implement post-closure monitoring, and complete other remediation, as required.

h. Operators may be subject to local requirements for zoning and construction of facilities and shall provide copies of any approval notices, permits, or other similar types of notifications for the facility from local governments or other agencies to the Director for review prior to issuance of the operating permit.

909. SITE INVESTIGATION, REMEDIATION, AND CLOSURE

a. **Applicability.** This section applies to the closure and remediation of pits other than drilling pits constructed pursuant to Rule 903.a.(3); investigation, reporting and remediation of spills/releases; permitted waste management facilities including treatment facilities; plugged and abandoned wellsites; sites impacted by E&P waste management practices; or other sites as designated by the Director.

b. **General site investigation and remediation requirements.**

(1) **Sensitive Area Determination.** Operators shall complete a sensitive area determination in accordance with Rule 901.e.

(2) **Sampling and analyses.** Sampling and analysis of soil and ground water shall be conducted in accordance with Rule 910. to determine the horizontal and vertical extent of any contamination in excess of the concentrations in Table 910-1.

(3) **Management of E&P waste.** E&P waste shall be managed in accordance with Rule 907.

(4) **Pit evacuation.** Prior to backfilling and site reclamation, E&P waste shall be treated or disposed in accordance with Rule 907. and the 1000 Series rules.

(5) **Remediation.** Remediation shall be performed in a manner to mitigate, remove, or reduce contamination that exceeds the concentrations in Table 910-1 in order to ensure protection of public health, safety, and welfare, and to prevent and mitigate significant adverse environmental impacts. Soil that does not meet concentrations in Table 910-1 shall be remediated. Ground water that does not meet concentrations in Table 910-1 shall be remediated in accordance with a Site Investigation and Remediation Workplan, Form 27.

(6) **Reclamation.** Remediation sites shall be reclaimed in accordance with the 1000 Series rules for reclamation.

c. **Site Investigation And Remediation Workplan, Form 27.** Operators shall prepare and submit for prior Director approval a Site Investigation and Remediation Workplan, Form 27, for the following operations and remediation activities:

(1) Unlined pit closure when required by Rule 905.

(2) Remediation of spills/releases in accordance with Rule 906.

(3) Land treatment of oily waste in accordance with Rule 907.e.(2).F.

(4) Closure of centralized E&P waste management facilities in accordance with Rule 908.g.

(5) Remediation of impacted ground water in accordance with Rule 910.b.(4).

d. **Multiple sites.** Remediation of multiple sites may be submitted on a single workplan with prior Director approval.

e. **Closure.**

(1) Remediation and reclamation shall be complete upon compliance with the concentrations in Table 910-1, or upon compliance with an approved workplan.

(2) **Notification of completion.** Within thirty (30) days after conclusion of site remediation and reclamation activities operators shall provide the following notification of completion:

A. Operators conducting remediation operations in accordance with Rule 909.b. shall submit to the Director a Site Investigation and Remediation Workplan, Form 27, containing information sufficient to demonstrate compliance with these rules.

B. Operators conducting remediation under an approved workplan shall submit to the Director, by adding or attaching to the original workplan, information sufficient to demonstrate compliance with the workplan.

f. **Release of financial assurance.** Financial assurance required by Rule 706. may be held by the Director until the required remediation of soil and/or ground water impacts is completed in accordance with the approved workplan, or until cleanup goals are met.

910. CONCENTRATIONS AND SAMPLING FOR SOIL AND GROUND WATER

a. **Soil and groundwater concentrations.** The concentrations for soil and ground water are in Table 910-1. Ground water standards and analytical methods are derived from the ground water standards and classifications established by WQCC.

b. **Sampling and analysis.**

(1) **Existing workplans.** Sampling and analysis for sites subject to an approved workplan shall be conducted in accordance with the workplan and the sampling and analysis requirements described in this rule.

(2) **Methods for sampling and analysis.** Sampling and analysis for site investigation or confirmation of successful remediation shall be conducted to determine the

nature and extent of impact and confirm compliance with appropriate concentration levels in Table 910-1.

A. **Field analysis.** Field measurements and field tests shall be conducted using appropriate equipment, calibrated and operated according to manufacturer specifications, by personnel trained and familiar with the equipment.

B. **Sample collection.** Samples shall be collected, preserved, documented, and shipped using standard environmental sampling procedures in a manner to ensure accurate representation of site conditions.

C. **Laboratory analytical methods.** Laboratories shall analyze samples using standard methods (such as EPA SW-846 or API RP-45) appropriate for detecting the target analyte. The method selected shall have detection limits less than or equal to the concentrations in Table 910-1.

D. **Background sampling.** Samples of comparable, nearby, non-impacted, native soil, ground water or other medium may be required by the Director for establishing background conditions.

(3) **Soil sampling and analysis.**

A. **Applicability.** If soil contamination is suspected or known to exist as a result of spills/releases or E&P waste management, representative samples of soil shall be collected and analyzed in accordance with this rule.

B. **Sample collection.** Samples shall be collected from areas most likely to have been impacted, and the horizontal and vertical extent of contamination shall be determined. The number and location of samples shall be appropriate to the impact.

C. **Sample analysis.** Soil samples shall be analyzed for contaminants listed in Table 910-1 as appropriate to assess the impact or confirm remediation. The analytical parameters shall be selected based on site-specific conditions and process knowledge and shall be agreed to and approved by the Director.

D. **Reporting.** Soil Analysis Report, Form 24, shall be used when the Director requires results of soil analyses.

E. **Soil impacted by produced water.** For impacts to soil due to produced water, samples from comparable, nearby non-impacted native soil shall be collected and analyzed for purposes of establishing background soil conditions including pH and electrical conductivity (EC). Where EC of the impacted soil exceeds the level in Table 910-1, the sodium adsorption ratio (SAR) shall also be determined.

F. **Soil impacted by hydrocarbons.** For impacts to soil due to hydrocarbons, samples shall be analyzed for TPH.

(4) **Ground water sampling and analysis.**

A. **Applicability.** Operators shall collect and analyze representative samples of ground water in accordance with these rules under the following circumstances:

(i) Where ground water contamination is suspected or known to exceed the concentrations in Table 910-1;

(ii) Where impacted soils are in contact with ground water; or

(iii) Where impacts to soils extend down to the high water table.

B. **Sample collection.** Samples shall be collected from areas most likely to have been impacted, downgradient or in the middle of excavated areas. The number and location of samples shall be appropriate to determine the horizontal and vertical extent of the impact. If the concentrations in Table 910-1 are exceeded, the direction of flow and a ground water gradient shall be established, unless the extent of the contamination and migration can otherwise be adequately determined.

C. **Sample analysis.** Ground water samples shall be analyzed for benzene, toluene, ethylbenzene, xylene, and API RP-45 constituents, or other parameters appropriate for evaluating the impact. The analytical parameters shall be selected based on site-specific conditions and process knowledge and shall be agreed to and approved by the Director.

D. **Reporting.** Water Analysis Report, Form 25, shall be used when the Director requires results of water analyses.

E. **Impacted ground water.** Where ground water contaminants exceed the concentrations listed in Table 910-1, operators shall notify the Director and submit to the Director for prior approval a Site Investigation and Remediation Workplan, Form 27, for the investigation, remediation, or monitoring of ground water to meet the required concentrations in Table 910-1.

911. PIT, BURIED OR PARTIALLY BURIED PRODUCED WATER VESSEL, BLOWDOWN PIT, AND BASIC SEDIMENT/TANK BOTTOM PIT MANAGEMENT REQUIREMENTS PRIOR TO DECEMBER 30, 1997.

a. **Applicability.** This rule applies to the management, operation, closure and remediation of drilling, production and special purpose pits, buried or partially buried produced water vessels, blowdown pits, and basic sediment/tank bottom pits put into service prior to December 30, 1997 and unlined skim pits put into service prior to July 1, 1995. For pits constructed after December 30, 1997 and skim pits constructed after July 1, 1995, operators shall comply with the requirements contained in Rules 901. through 910.

b. **Inventory.** Operators were required to submit to the Director no later than December 31, 1995, an inventory identifying production pits, buried or partially buried produced water vessels, blowdown pits, and basic sediment/tank bottom pits that existed on June 30, 1995. The inventory required operators to provide the facility name, a description of the location, type, capacity and use of pit/vessel, whether netted or fenced, lined or unlined, and where available, water quality data. Operators who have failed to submit the required inventory are in continuing violation of this rule.

c. **Sensitive area determination.**

(1) For unlined production and special purpose pits constructed prior to July 1, 1995 and not closed by December 30, 1997, operators were required to determine whether the pit was located within a sensitive area in accordance with the Sensitive Area Determination Decision Tree, Figure 901-1 (now Rule 901.e.) and submit data evaluated and analysis used in the determination to the Director on a Sundry Notice, Form 4. In December 2008, Figure 901-1 was deleted from the 900-Series Rules.

(2) For steel, fiberglass, concrete, or other similar produced water vessels that were buried or partially buried and located in sensitive areas prior to December 30, 1997, operators were required to test such vessels for integrity, unless a monitoring or leak detection system was put in place.

d. The following permitting/reporting requirements applied to pits constructed prior to December 30, 1997:

(1) A Sundry Notice, Form 4, including the name, address, and phone number of the primary contact person operating the production pit for the operator, the facility name, a description of the location, type, capacity and use of pit, engineering design, installation features and water quality data, if available, was required for the following:

A. Lined production pits and lined special purpose pits constructed after July 1, 1995.

B. Unlined production pits constructed prior to July 1, 1995 which are lined in accordance with Rule 905. by December 30, 1997.

(2) An Application For Permit For Unlined Pit, Form 15 was required for the following:

A. Unlined production pits and special purpose pits in sensitive areas constructed prior to July 1, 1995, and not closed by December 30, 1997.

B. Unlined production pits outside sensitive areas constructed after July 1, 1995 and not closed by December 30, 1997.

(3) An Application For Permit For Unlined Pit, Form 15 and a variance under Rule 904.e.(1). (repealed, now Rule 502.b.) was required for unlined production pits and unlined special purpose pits in sensitive areas constructed after July 1, 1995.

(4) A Sundry Notice, Form 4 was required for unlined production pits outside sensitive areas receiving produced water at an average daily rate of five (5) or less barrels per day calculated on a monthly basis for each month of operation constructed prior to December 30, 1997.

e. The Director may have established points of compliance for unlined production pits and special purpose pits and for lined production pits in sensitive areas constructed after July 1, 1995.

f. **Closure requirements.**

(1) Operators of production or special purpose pits existing on July 1, 1995 which were closed before December 30, 1997, were required to submit a Sundry Notice,

Form 4, within thirty (30) days of December 30, 1997. The Sundry Notice, Form 4 shall include a copy of the existing pit permit, if a permit was obtained, and a description of the closure process.

(2) Pits closed prior to December 30, 1997 were required to be reclaimed in accordance with the 1000 Series rules. Pits closed after December 30, 1997 shall be closed in accordance with the 900 Series rules and reclaimed in accordance with the 1000 Series rules.

(3) Operators of steel, fiberglass, concrete or other similar produced water vessels buried or partially buried and located in sensitive areas were required to repair or replace vessels and tanks found to be leaking. Operators shall repair or replace vessels and tanks found to be leaking. Operators shall submit to the Director a Sundry Notice, Form 4, describing the integrity testing results and action taken within thirty (30) days of December 30, 1997.

(4) Closure of pits and steel, fiberglass, concrete or other similar produced water vessels, and associated remediation operations conducted prior to December 30, 1997 are not subject to Rules 905., 906., 907., 909. and 910.

912. VENTING OR FLARING NATURAL GAS

a. The unnecessary or excessive venting or flaring of natural gas produced from a well is prohibited.

b. Except for gas flared or vented during an upset condition, well maintenance, well stimulation flowback, purging operations, or a productivity test, gas from a well shall be flared or vented only after notice has been given and approval obtained from the Director on a Sundry Notice, Form 4, stating the estimated volume and content of the gas. The notice shall indicate whether the gas contains more than one (1) ppm of hydrogen sulfide. If necessary to protect the public health, safety or welfare, the Director may require the flaring of gas.

c. Gas flared, vented or used on the lease shall be estimated based on a gas-oil ratio test or other equivalent test approved by the Director, and reported on Operator's Monthly Production Report, Form 7.

d. Flared gas that is subject to Sundry Notice, Form 4, shall be directed to a controlled flare in accordance with Rule 903.b.(2) or other combustion device operated as efficiently as possible to provide maximum reduction of air contaminants where practicable and without endangering the safety of the well site personnel and the public.

e. Operators shall notify the local emergency dispatch or the local governmental designee of any natural gas flaring. Notice shall be given prior to flaring when flaring can be reasonably anticipated, or as soon as possible, but in no event more than two (2) hours after the flaring occurs.

Table 910-1

Contaminant of Concern	Concentrations
Organic Compounds in Soil	
TPH (total volatile and extractable petroleum hydrocarbons)	500 mg/kg
Benzene	0.17 mg/kg[2]
Toluene	85 mg/kg[2]
Ethylbenzene	100 mg/kg[2]
Xylenes (total	175 mg/kg[2]
Acenaphthene	1,000 mg/kg[2]
Anthracene	1,000 mg/kg[2]
Benzo(A)anthracene	0.22 mg/kg[2]
Benzo(B)fluoranthene	0.22 mg/kg[2]
Benzo(K)fluoranthene	2.2 mg/kg[2]
Benzo(A)pyrene	0.022 mg/kg[2]
Chrysene	22 mg/kg[2]
Dibenzo(A,H)anthracene	0.022 mg/kg[2]
Fluoranthene	1,000 mg/kg[2]
Fluorene	1,000 mg/kg[2]
Indeno(1,2,3,C,D)pyrene	0.22 mg/kg[2]
Napthalene	23 mg/kg[2]
Pyrene	1,000 mg/kg[2]
Organic Compounds in Ground Water	
Benzene	5 µg/l[3]
Toluene	560 to 1,000 µg/l[3]
Ethylbenzene	700 µg/l[3]
Xylenes (Total)	1,400 to 10,000 µg/l[3,4]
Inorganics in Soils	
Electrical Conductivity (EC)	<4 mmhos/cm or 2x background
Sodium Adsorption Ratio (SAR)	<12[5]
pH	6-9
Inorganics in Ground Water	
Total Dissolved Solids (TDS)	<1.25 x background[3]
Chlorides	<1.25 x background[3]
Sulfates	<1.25 x background[3]
Metals in Soils	
Arsenic	0.39 mg/kg[2]
Barium (LDNR True Total Barium)	15,000 mg/kg[2]
Boron (Hot Water Soluble)	2 mg/l[3]
Cadmium	70 mg/kg[3,6]
Chromium (III)	120,000 mg/kg[2]
Chromium (VI)	23 mg/kg[2,6]
Copper	3,100 mg/kg[2]
Lead (inorganic)	400 mg/kg[2]
Mercury	23 mg/kg[2]
Nickel (soluble salts)	1,600 mg/kg[2,6]
Selenium	390 mg/kg[2,6]
Silver	390 mg/kg[2]
Zinc	23,000 mg/kg[2,6]
Liquid Hydrocarbons in Soils and Ground Water	
Liquid hydrocarbons including condensate and oil	Below detection level

Notes to Table 3

COGCC recommends that the latest version of EPA SW 846 analytical methods be used where possible and that analyses of samples be performed by laboratories that maintain state or national accreditation programs.

[1] Consideration shall be given to background levels in native soils and ground water.

[2] Concentrations taken from CDPHE-HMWMD Table 1 Colorado Soil Evaluation Values (December 2007).

[3] Concentrations taken from CDPHE-WQCC Regulation 41 - The Basic Standards for Ground Water.

[4] For this range of standards, the first number in the range is a strictly health-based value, based on the WQCC's established methodology for human health-based standards. The second number in the range is a maximum contaminant level (MCL), established under the Federal Safe Drinking Water Act which has been determined to be an acceptable level of this chemical in public water supplies, taking treatability and laboratory detection limits into account. The WQCC intends that control requirements for this chemical be implemented to attain a level of ambient water quality that is at least equal to the first number in the range except as follows: 1) where ground water quality exceeds the first number in the range due to a release of contaminants that occurred prior to September 14, 2004 (regardless of the date of discovery or subsequent migration of such contaminants) clean-up levels for the entire contaminant plume shall be no more restrictive than the second number in the range or the ground water quality resulting from such release, whichever is more protective, and 2) whenever the WQCC has adopted alternative, site-specific standards for the chemical, the site-specific standards shall apply instead of these statewide standards.

[5] Analysis by USDA Agricultural Handbook 60 method (20B) with soluble cations determined by method (2). Method (20B) = estimation of exchangeable sodium percentage and exchangeable potassium percentage from soluble cations. Method (2) = saturated paste method (note: each analysis requires a unique sample of at least 500 grams). If soils are saturated, USDA Agricultural Handbook 60 with soluble cations determined by method (3A) saturation extraction method.

[6] The table value for these inorganic constituents is taken from the CDPHE-HMWMD Table 1 Colorado Soil Evaluation Values (December 2007). However, because these values are high, it is possible that site-specific geochemical conditions may exist that could allow these constituents to migrate into ground water at levels exceeding ground water standards even though the concentrations are below the table values. Therefore, when these constituents are present as contaminants, a secondary evaluation of their leachability must be performed to ensure ground water protection.

APPENDIX C – Permits

149002

STATE OF COLORADO
OIL & GAS
CONSERVATION COMMISSION

DEPARTMENT OF NATURAL RESOURCES
Bill Owens, Governor
1120 Lincoln St.; Suite 801
Denver, CO 80203
Phone: (303) 894-2100
FAX: (303) 894-2109
www.oil-gas.state.co.us

December 1, 2000

Mr. Rached Hindi
Texaco Exploration and Production Inc.
4601 DTC Blvd.
Denver, Colorado 80237

RE: Wilson Creek Field Centralized E&P Waste Management Facility
Permit Application Approval
Rio Blanco County, Colorado
COGCC CE&P Waste Management Facility No. 149002

Dear Mr. Hindi:

The Colorado Oil & Gas Conservation Commission (COGCC) staff is in receipt of the financial assurance documentation as requested in our correspondence of September 20, 2000. The COCGG approves Texaco's application for the Centralized E&P Waste Management Facility (Facility) at Wilson Creek Field. Please note that the COGCC staff will periodically inspect the Facility for compliance with the operating plan included in the permit and will include:

- Proof that the maximum volume of treated soil at any one time will not exceed 30 cubic yards, and
- Repair and maintenance of the Facility's liner are sufficient to prevent migration of E&P contaminants into the subsurface.

Should future conditions at the facility be discovered that are in violation of Texaco's operating permit or if there's a need to expand the Facility to accommodate treatment of additional soils, the COGCC director may required additional conditions to this permit, including installation of ground water monitoring wells. If you have any questions or wish to discuss this site further, please call me at (303) 894-2100 ext.112 or via e-mail at robert.chesson@state.co.us.

Sincerely,

Robert H. Chesson, C.P.G., P.G.
Environmental Protection Specialist

cc: Rich Griebling – COGCC
Debbie Baldwin – COGCC

00881915

FORM 4
Rev 12/05

State of Colorado
Oil and Gas Conservation Commission

1120 Lincoln Street, Suite 801, Denver, Colorado 80203 Phone: (303)894-2100 Fax:(303)894-2109

RECEIVED
OCT 25 2010
COGCC

SUNDRY NOTICE

Submit original plus one copy. This form is to be used for general, technical and environmental sundry information. For proposed or completed operations, describe in full on Technical Information Page (Page 2 of this form.) Identify well or other facility by API Number or by OGCC Facility ID. Operator shall send an informational copy of all sundry notices for wells located in High Density Areas to the Local Government Designee (Rule 603b.)

1. OGCC Operator Number: 16700
2. Name of Operator: Chevron USA, Inc.
3. Address: 7265 Rio Blanco County Road #9
City: Meeker State: CO Zip: 81641
4. Contact Name: Stephen Gwin
Phone: (432) 687-7575
Fax: (866) 569-5650

Complete the Attachment Checklist

	OP	OGCC
Survey Plat		
Directional Survey		
Surface Eqpmt Diagram		
Technical Info Page		
Other Landfarm Liner	X	

5. API Number 05- Not applicable
OGCC Facility ID Number 149002
6. Well/Facility Name: Wilson Creek Landfarm
7. Well/Facility Number Not applicable
8. Location (QtrQtr, Sec, Twp, Rng, Meridian): NE NW,Sec 35, T3N, R94W, 6th P.M.
9. County: Rio Blanco
10. Field Name: Wilson Creek
11. Federal, Indian or State Lease Number:

General Notice

☐ CHANGE OF LOCATION: Attach New Survey Plat (a change of surface qtr/qtr is substantive and requires a new permit)

		FNL/FSL		FEL/FWL
Change of **Surface** Footage **from** Exterior Section Lines:				
Change of **Surface** Footage **to** Exterior Section Lines:				
Change of **Bottomhole** Footage **from** Exterior Section Lines:				
Change of **Bottomhole** Footage **to** Exterior Section Lines:				

attach directional survey

Bottomhole location Qtr/Qtr, Sec, Twp, Rng, Mer
Latitude — Distance to nearest property line — Distance to nearest bldg, public rd, utility or RR
Longitude — Distance to nearest lease line — Is location in a High Density Area (rule 603b)? Yes/No
Ground Elevation — Distance to nearest well same formation — Surface owner consultation date:

GPS DATA:
Date of Measurement — PDOP Reading — Instrument Operator's Name

☐ CHANGE SPACING UNIT

Formation	Formation Code	Spacing order number	Unit Acreage	Unit configuration

☐ Remove from surface bond
Signed surface use agreement attached

☐ CHANGE OF OPERATOR (prior to drilling):
Effective Date:
Plugging Bond: ☐ Blanket ☐ Individual

☐ CHANGE WELL NAME — NUMBER
From:
To:
Effective Date:

☐ ABANDONED LOCATION:
Was location ever built? ☐ Yes ☐ No
Is site ready for Inspection? ☐ Yes ☐ No
Date Ready for Inspection:

☐ NOTICE OF CONTINUED SHUT IN STATUS
Date well shut in or temporarily abandoned:
Has Production Equipment been removed from site? ☐ Yes ☐ No
MIT required if shut in longer than two years. Date of last MIT

☐ SPUD DATE:

☐ REQUEST FOR CONFIDENTIAL STATUS (6 mos from date casing set)

☐ SUBSEQUENT REPORT OF STAGE, SQUEEZE OR REMEDIAL CEMENT WORK *submit cbl and cement job summaries

Method used	Cementing tool setting/perf depth	Cement volume	Cement top	Cement bottom	Date

☐ RECLAMATION: Attach technical page describing final reclamation procedures per Rule 1004.
Final reclamation will commence on approximately
☐ Final reclamation is completed and site is ready for inspection.

Technical Engineering/Environmental Notice

☒ Notice of Intent
Approximate Start Date: October 18, 2010

☐ Report of Work Done
Date Work Completed:

Details of work must be described in full on Technical Information Page (Page 2 must be submitted.)

☐ Intent to Recomplete (submit form 2)
☐ Change Drilling Plans
☐ Gross Interval Changed?
☐ Casing/Cementing Program Change
☐ Request to Vent or Flare
☐ Repair Well
☐ Rule 502 variance requested
☒ Other: Landfarm liner modification
☐ E&P Waste Disposal
☐ Beneficial Reuse of E&P Waste
☐ Status Update/Change of Remediation Plans for Spills and Releases

I hereby certify that the statements made in this form are, to the best of my knowledge, true, correct and complete.

Signed: [signature] Date: 10/21/10 Email: gwst@chevron.com
Print Name: Stephen Gwin Title: Environmental Specialist - Waste and Water

COGCC Approved: [signature] Title: EPS IV Date: 10/29/10

CONDITIONS OF APPROVAL, IF ANY:

Provide Closure Cost Estimate per Rule 908.g.(1)B.

FORM 4 Rev 12/05 Page 2

TECHNICAL INFORMATION PAGE

RECEIVED OCT 25 2010 COGCC

1. OGCC Operator Number: 16700	API Number: Not applicable
2. Name of Operator: Chevron USA, Inc.	OGCC Facility ID # 149002
3. Well/Facility Name: Wilson Creek Landfarm	Well/Facility Number: Not applicable
4. Location (QtrQtr, Sec, Twp, Rng, Meridian): NE NW, Sec 35, T3N, R94W, 6th P.M.	

This form is to be completed whenever a Sundry Notice is submitted requiring detailed report of work to be performed or completed. This form shall be transmitted within 30 days of work completed as a "subsequent" report and must accompany Form 4, page 1.

5. **DESCRIBE PROPOSED OR COMPLETED OPERATIONS**

Chevron proposes to upgrade and expand the lined portion of the Wilson Creek Landfarm (Facility No. 149002). A scaled survey drawing describing the proposed modification, along with liner and liner foundation specifications, is attached.

Attachment -
Wilson Creek - Waste Management Facility, Proposed Lined Area, dated 10-7-2010.

Background -

As documented in the attached COGCC letters, the Wilson Creek Landfarm was originally permitted to Texaco Exploration and Production in December 2000. In July 2003, approval was granted for an unlined expansion of the landfarm on the condition that "wet" type wastes were prohibited from being applied to the unlined portion of the landfarm.

Attachments -
Approval Letter, Original Landfarm - December 1, 2000
Approval Letter, Landfarm Expansion - July 2, 2003

Modification Request -

In this modification, Chevron is requesting permission to expand, deepen, and upgrade the lined portion of the landfarm as shown in the attached drawing, "Wilson Creek - Waste Management Facility, Proposed Lined Area". Since there is no specific rule or guidance on landfarm liners, Chevron will use the COGCC specfications for pit liners (Rule 904(c)) as the minimum specification for the landfarm liner, including a minimum liner thickness of 24 mils and a twelve (12) inch liner foundation compacted so that the hydraulic conductivity does not exceed 1.0 x 10^(-7) cm/sec. A full description of the liner installation and specification is contained in the attached drawing.

In addition, Chevron agrees to install three (3) groundwater monitoring wells - two (2) downgradient and one (1) upgradient, approximately located as shown on the engineering drawing attached. The precise location of the groundwater monitoring wells will be selected on the basis of an on-site inspection and determination of the most suitable location for monitoring groundwater.

The risk of surface water contamination is low due to the location of the landfarm and distance to surface water. Attached are a series of maps on different scales showing the landfarm location, topography, and nearest surface water.

Figure 1 - General Area Topographic
Figure 2 - Area Detail Topographic
Figure 3 - Landfarm Boundary
Figure 4 - Distance to Surface Water

Form No. GWS-25

OFFICE OF THE STATE ENGINEER
COLORADO DIVISION OF WATER RESOURCES

818 Centennial Bldg., 1313 Sherman St., Denver, Colorado 80203
(303) 866-3581

EXST

WELL PERMIT NUMBER 289839 - -
DIV. 6 WD 44 DES. BASIN MD

APPLICANT

CHEVRON ENVIRONMENTAL MGMT COMPANY
ATTN ERIC PAGE
1400 SMITH ST RM 40029
HOUSTON, TX 77022-

(713) 372-1022

APPROVED WELL LOCATION
RIO BLANCO COUNTY
NE 1/4 NW 1/4 Section 32
Township 3 N Range 94 W Sixth P.M.

DISTANCES FROM SECTION LINES
688 Ft. from North Section Line
1389 Ft. from West Section Line

UTM COORDINATES (Meters,Zone:13,NAD83)
Easting: Northing:

PERMIT TO USE AN EXISTING WELL

ISSUANCE OF THIS PERMIT DOES NOT CONFER A WATER RIGHT

CONDITIONS OF APPROVAL

1) This well shall be used in such a way as to cause no material injury to existing water rights. The issuance of this permit does not ensure that no injury will occur to another vested water right or preclude another owner of a vested water right from seeking relief in a civil court action.
2) The construction of this well shall be in compliance with the Water Well Construction Rules 2 CCR 402-2, unless approval of a variance has been granted by the State Board of Examiners of Water Well Construction and Pump Installation Contractors in accordance with Rule 18.
3) Approved pursuant to CRS 37-92-602(3)(b)(I) for uses as described in CRS 37-92-602(1)(f). Use of this well is limited to monitoring water levels and/or water quality sampling.
4) Approved for the use of an existing well known as MW-50.
5) This well must be equipped with a locking cap or seal to prevent well contamination or possible hazards as an open well. The well must be kept capped and locked at all times except during sampling or measuring.
6) Records of water level measurements and water quality analyses shall be maintained by the well owner and submitted to the Division of Water Resources upon request.
7) Upon conclusion of the monitoring program the well owner shall plug this well in accordance with Rule 16 of the Water Well Construction Rules. A Well Abandonment Report must be completed and submitted to the Division of Water Resources within 60 days of plugging.
8) The owner shall mark the well in a conspicuous place with the well permit number and name of aquifer as appropriate, and shall take necessary means and precautions to preserve these markings.
9) This well must have been constructed by or under the supervision of a licensed well driller or other authorized individual according to the Water Well Construction Rules.
10) This well must be located not more than 200 feet from the location specified on this permit.

NOTE: Issuance of this permit does not guarantee that this well can be converted to a production well under a future permit. Additionally, pursuant to Rule 14.2 of the Water Well Construction Rules (2 CCR 402-2), monitoring holes constructed pursuant to a monitoring hole notice shall not be converted to a production well. (Upon obtaining a permit from the State Engineer, a monitoring hole may be converted to a monitoring well, recovery well for remediation of the aquifer, or a dewatering system for dewatering the aquifer.) AP 11-20-12

APPROVED

Dick Wolfe
State Engineer

By

Receipt No. 3657664C DATE ISSUED 11-20-2012 EXPIRATION DATE N/A

Form No. GWS-25

OFFICE OF THE STATE ENGINEER
COLORADO DIVISION OF WATER RESOURCES

818 Centennial Bldg., 1313 Sherman St., Denver, Colorado 80203
(303) 866-3581

EXST

WELL PERMIT NUMBER 289838 - -
DIV. 6 WD 44 DES. BASIN MD

APPLICANT

CHEVRON ENVIRONMENTAL MGMT COMPANY
ATTN ERIC PAGE
1400 SMITH ST RM 40029
HOUSTON, TX 77022-

(713) 372-1022

APPROVED WELL LOCATION
RIO BLANCO COUNTY
NE 1/4 NW 1/4 Section 35
Township 3 N Range 94 W Sixth P.M.

DISTANCES FROM SECTION LINES
864 Ft. from North Section Line
2017 Ft. from West Section Line

UTM COORDINATES (Meters,Zone:13,NAD83)
Easting: Northing:

PERMIT TO USE AN EXISTING WELL

ISSUANCE OF THIS PERMIT DOES NOT CONFER A WATER RIGHT

CONDITIONS OF APPROVAL

1) This well shall be used in such a way as to cause no material injury to existing water rights. The issuance of this permit does not ensure that no injury will occur to another vested water right or preclude another owner of a vested water right from seeking relief in a civil court action.
2) The construction of this well shall be in compliance with the Water Well Construction Rules 2 CCR 402-2, unless approval of a variance has been granted by the State Board of Examiners of Water Well Construction and Pump Installation Contractors in accordance with Rule 18.
3) Approved pursuant to CRS 37-92-602(3)(b)(I) for uses as described in CRS 37-92-602(1)(f). Use of this well is limited to monitoring water levels and/or water quality sampling.
4) Approved for the use of an existing well known as MW-49.
5) This well must be equipped with a locking cap or seal to prevent well contamination or possible hazards as an open well. The well must be kept capped and locked at all times except during sampling or measuring.
6) Records of water level measurements and water quality analyses shall be maintained by the well owner and submitted to the Division of Water Resources upon request.
7) Upon conclusion of the monitoring program the well owner shall plug this well in accordance with Rule 16 of the Water Well Construction Rules. A Well Abandonment Report must be completed and submitted to the Division of Water Resources within 60 days of plugging.
8) The owner shall mark the well in a conspicuous place with the well permit number and name of aquifer as appropriate, and shall take necessary means and precautions to preserve these markings.
9) This well must have been constructed by or under the supervision of a licensed well driller or other authorized individual according to the Water Well Construction Rules.
10) This well must be located not more than 200 feet from the location specified on this permit.

NOTE: Issuance of this permit does not guarantee that this well can be converted to a production well under a future permit. Additionally, pursuant to Rule 14.2 of the Water Well Construction Rules (2 CCR 402-2), monitoring holes constructed pursuant to a monitoring hole notice shall not be converted to a production well. (Upon obtaining a permit from the State Engineer, a monitoring hole may be converted to a monitoring well, recovery well for remediation of the aquifer, or a dewatering system for dewatering the aquifer.) AT 11-20-12

APPROVED

State Engineer Dick Wolfe

By [signature]

Receipt No. 3657664B DATE ISSUED 11-20-2012 EXPIRATION DATE N/A

Form No. GWS-25

OFFICE OF THE STATE ENGINEER
COLORADO DIVISION OF WATER RESOURCES

818 Centennial Bldg., 1313 Sherman St., Denver, Colorado 80203
(303) 866-3581

EXST

WELL PERMIT NUMBER 289837 - -
DIV. 6 WD 44 DES. BASIN MD

APPLICANT

CHEVRON ENVIRONMENTAL MGMT COMPANY
ATTN ERIC PAGE
1400 SMITH ST RM 40029
HOUSTON, TX 77022-

(713) 372-1022

APPROVED WELL LOCATION
RIO BLANCO COUNTY
NE 1/4 NW 1/4 Section 35
Township 3 N Range 94 W Sixth P.M.

DISTANCES FROM SECTION LINES
814 Ft. from North Section Line
2429 Ft. from West Section Line

UTM COORDINATES (Meters,Zone:13,NAD83)
Easting: Northing:

PERMIT TO USE AN EXISTING WELL

ISSUANCE OF THIS PERMIT DOES NOT CONFER A WATER RIGHT

CONDITIONS OF APPROVAL

1) This well shall be used in such a way as to cause no material injury to existing water rights. The issuance of this permit does not ensure that no injury will occur to another vested water right or preclude another owner of a vested water right from seeking relief in a civil court action.
2) The construction of this well shall be in compliance with the Water Well Construction Rules 2 CCR 402-2, unless approval of a variance has been granted by the State Board of Examiners of Water Well Construction and Pump Installation Contractors in accordance with Rule 18.
3) Approved pursuant to CRS 37-92-602(3)(b)(I) for uses as described in CRS 37-92-602(1)(f). Use of this well is limited to monitoring water levels and/or water quality sampling.
4) Approved for the use of an existing well known as MW-48.
5) This well must be equipped with a locking cap or seal to prevent well contamination or possible hazards as an open well. The well must be kept capped and locked at all times except during sampling or measuring.
6) Records of water level measurements and water quality analyses shall be maintained by the well owner and submitted to the Division of Water Resources upon request.
7) Upon conclusion of the monitoring program the well owner shall plug this well in accordance with Rule 16 of the Water Well Construction Rules. A Well Abandonment Report must be completed and submitted to the Division of Water Resources within 60 days of plugging.
8) The owner shall mark the well in a conspicuous place with the well permit number and name of aquifer as appropriate, and shall take necessary means and precautions to preserve these markings.
9) This well must have been constructed by or under the supervision of a licensed well driller or other authorized individual according to the Water Well Construction Rules.
10) This well must be located not more than 200 feet from the location specified on this permit.

NOTE: Issuance of this permit does not guarantee that this well can be converted to a production well under a future permit. Additionally, pursuant to Rule 14.2 of the Water Well Construction Rules (2 CCR 402-2), monitoring holes constructed pursuant to a monitoring hole notice shall not be converted to a production well. (Upon obtaining a permit from the State Engineer, a monitoring hole may be converted to a monitoring well, recovery well for remediation of the aquifer, or a dewatering system for dewatering the aquifer.) AP 11-20-12

APPROVED

Dick Wolfe
State Engineer

By

Receipt No. 3657664A DATE ISSUED 11-20-2012 EXPIRATION DATE N/A

APPENDIX D – ASTM Guidance Documents

ASTM D6009 – Standard Guide for Sampling Waste Piles

ASTM D6044 – Standard Guide for Representative Sampling for Management of Waste and Contaminated Media

Designation: D 6009 – 96 (Reapproved 2001)

Standard Guide for Sampling Waste Piles[1]

This standard is issued under the fixed designation D 6009; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This guide provides guidance for obtaining representative samples from waste piles. Guidance is provided for site evaluation, sampling design, selection of equipment, and data interpretation.

1.2 Waste piles include areas used primarily for waste storage or disposal, including above-grade dry land disposal units. This guide can be applied to sampling municipal waste piles.

1.3 This guide addresses how the choice of sampling design and sampling methods depends on specific features of the pile.

1.4 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*

D 1452 Practice for Soil Investigation and Sampling by Auger Borings[2]

D 1586 Test Method for Penetration Test and Split-Barrel Sampling of Soils[2]

D 1587 Practice for Thin-Walled Tube Geotechnical Sampling of Soils[2]

D 4547 Practice for Sampling Waste and Soils for Volatile Organics[3]

D 4687 Guide for General Planning of Waste Sampling[3]

D 4700 Guide for Soil Sampling from the Vadose Zone[2]

D 4823 Guide for Core-Sampling Submerged, Unconsolidated Sediments[4]

D 5088 Practice for Decontamination of Field Equipment Used at Nonradioactive Sites[5]

D 5314 Guide for Soil Gas Monitoring in the Vadose Zone[5]

D 5451 Practice for Sampling Using a Trier Sampler[3]

D 5518 Guide for Acquisition of File Aerial Photography and Imagery for Establishing Historic Site-Use and Surficial Conditions[5]

D 5730 Guide to Site Characterization for Environmental Purposes with Emphasis on Soil, Rock, the Vadose Zone and Ground Water[5]

3. Terminology

3.1 *Definitions of Terms Specific to This Standard:*

3.1.1 *hot spots*—strata that contain high concentrations of the characteristic of interest and are relatively small in size when compared with the total size of the materials being sampled.

3.1.2 *representative sample*—a sample collected such that it reflects one or more characteristics of interest (as defined by the project objectives) of the population from which it was collected.

3.1.2.1 *Discussion*—A representative sample can be a single sample, a set of samples, or one or more composite samples.

3.1.3 *waste pile*—unconfined storage of solid materials in an area of distinct boundaries, above grade and usually uncovered. This includes the following:

3.1.3.1 *chemical manufacturing waste pile*—a pile consisting primarily of discarded chemical products (whether marketable or not), by-products, radioactive wastes, or used or unused feedstocks.

3.1.3.2 *scrap metal or junk pile*—a pile consisting primarily of scrap metal or discarded durable goods such as appliances, automobiles, auto parts, or batteries.

3.1.3.3 *trash pile*—a pile of waste materials from municipal sources, consisting primarily of paper, garbage, or discarded nondurable goods that contain or have contained hazardous substances. It does not include waste destined for recyclers.

4. Significance and Use

4.1 This guide is intended to provide guidance for sampling waste piles. It can be used to obtain samples for waste characterization related to use, treatment, or disposal; to monitor an active pile; to prepare for closure of the waste pile; or to investigate the contents of an abandoned pile.

4.2 Techniques used to sample include both in-place evaluations of the pile and physically removing a sample. In-place evaluations include techniques such as remote sensing, on-site gas analysis, and permeability.

4.3 Sampling strategy for waste piles is dependent on the following:

4.3.1 Project objectives including acceptable levels of error when making decisions;

---

[1] This guide is under the jurisdiction of ASTM Committee D34 on Waste Management and is the direct responsibility of Subcommittee D34.01.01 on Planning for Sampling.

Current edition approved Oct. 10, 1996. Published December 1996.

[2] *Annual Book of ASTM Standards*, Vol 04.08.

[3] *Annual Book of ASTM Standards*, Vol 11.04.

[4] *Annual Book of ASTM Standards*, Vol 11.02.

[5] *Annual Book of ASTM Standards*, Vol 04.09.

4.3.2 Physical characteristics of the pile, such as its size and configuration, access to all parts of it, and the stability of the pile;

4.3.3 Process that generated the waste and the waste characteristics, such as hazardous chemical or physical properties, whether the waste consists of sludges, dry powders or granules, and the heterogeneity of the wastes;

4.3.4 History of the pile, including dates of generation, methods of handling and transport, and current management methods;

4.3.5 Regulatory considerations, such as regulatory classification and characterization data;

4.3.6 Limits and bias of sampling methods, including bias that may be introduced by waste heterogeneity, sampling design, and sampling equipment.

4.4 It is recommended that this guide be used in conjunction with Guide D 4687, which addresses sampling design, quality assurance, general sampling considerations, preservation and containerization, cleaning equipment, packaging, and chain of custody.

4.5 A case history of the investigation of a waste pile is included in Appendix X1.

5. Site Evaluation

5.1 Site evaluations are performed to assist in designing the most appropriate sampling strategy. An evaluation may consist of on-site surveys and inspections, as well as a review of historical data. Nonintrusive geophysical and remote sensing methods are particularly useful at this stage of the investigation (see Guide D 5518). Table 1 summarizes the effects that various factors associated with the waste pile, such as the history of how the pile was generated, have upon the strategy and design of the sampling plan. The strategic and design considerations are discussed as well.

5.2 *Generation History*—The waste pile may have been created over an extended time period. A remote sensing method that is very useful in establishing historical management practices for waste piles is aerial imagery. Aerial photographs are widely available and may be used to determine the history of a waste pile, sources of waste, and the presence and distribution of different strata. Satellite imagery could be used for larger waste piles.

TABLE 1 Strategy Factors

Waste Pile Factors	Strategic Considerations	Design Considerations
Generation history	Date of generation	Analysis required
	Types of processes	Location of samples
	Characteristics by process	
	Delivery method	
	Current management	
	Regulatory considerations	
Physical characteristics of pile:	Physical variability of pile	Number of samples
– size	Access	Location of samples
– shape	Safety	Equipment selection
– stability		
Waste characteristics	Constituents present	Number of samples
	Constituent distribution	Analysis required
	Heterogeneity	Location of samples
	– physical variability	Representative samples
	– chemical variability	Equipment selection

5.2.1 The date of generation could be important with respect to the types of processes that generated the waste, the characteristics of the waste, the distribution of the constituents, and regulatory concerns.

5.2.2 The type of process that generated the waste will determine the types of constituents that may be present in the waste pile. Chemical variability will influence the number of samples that are required to characterize the waste pile unless a directed (biased) sampling approach is acceptable.

5.2.3 The delivery method of the material to the waste pile could influence the concentrations of the constituents, affect the overall shape of the pile, or create physical dissimilarity within the waste pile through sorting by particle size or density.

5.2.4 If the pile is under current management and use, the variability in constituent types and concentrations may be affected. Current management activities also may influence the regulatory status of the waste pile.

5.2.5 Regulatory considerations will typically focus on waste identification questions, in other words is the material a solid waste that should be regulated and managed as a hazardous waste **(1)**.[6] This may involve a limited, directed sampling approach, particularly if a regulatory agency is conducting the investigation. A more comprehensive sampling design may be required to determine if the waste classifies as hazardous. Remediation efforts and questions regarding permits may focus on characterizing the entire pile, possibly as the removal of material is occurring. It should be noted that concentrations of contaminants near regulatory levels may increase the number of samples required to meet the objectives of the investigation. These regulatory levels could be those established to determine if a waste is hazardous, or "cleanup" levels set for a removal or remediation.

5.3 *Physical Characteristics of Pile*— Several physical characteristics of the waste pile must be considered during the site evaluation. Variability in size, shape, and stability of the pile affects access to it to obtain samples as well as safety considerations. Physical variability will influence the number of samples that are required to characterize the waste pile unless a directed (biased) sampling approach is considered to be acceptable. Techniques that might be used include resistivity and seismic refraction (for determining the depth of very large piles).

5.3.1 The size of the waste pile will influence the sampling strategy in that increasing size is often accompanied by increased variability in the physical characteristics of the waste pile. The number of samples, however, that are needed to characterize a waste pile adequately will typically be a function of the study objectives as well as the inherent variability of the pile.

5.3.2 The shape of the waste pile can influence the sampling strategy by limiting access to certain locations within the pile, and if it is topologically complex it is difficult to lay out a sampling grid. Also, a waste pile may extend vertically both above and below grade, making decisions regarding the depth of sample collection difficult.

[6] The boldface numbers in parentheses refer to the list of references at the end of this standard.

5.3.3 The stability of the waste pile also can limit access to both the face and the interior of the pile. The use of certain types of heavier sampling equipment also could be limited by the ability of the pile to bear the weight of the equipment.

5.4 *Waste Characteristics*:

5.4.1 The constituents could include inorganics, volatile organic compounds (VOCs), and semivolatile organic compounds (including pesticides and polychlorinated biphenyls (PCBs)) (see Practice D 4547). Speciality analyses may be warranted, such as leaching tests or analyses for dioxin/furans or explosive compounds. Soil gas sampling is a minimally intrusive technique that may detect the presence and distribution of volatile organic compounds in soils and in porous, unconsolidated materials. Appropriate applications for soil gas monitoring are identified in Guide D 5314.

5.4.2 The distribution of constituents in the waste pile could be influenced by changes in the manufacturing process which resulted in changes in the composition of the waste; the length of time the material has remained in the pile (particularly for VOCs); the mode of delivery of the waste materials to the pile; and management practices, such as mixing together wastes from more than one process.

5.4.3 Physical and chemical variabilities would include variability in the chemical characteristics of the material within the pile, as well as variability in particle size, density, hardness, whether brittle or flexible, moisture content, consolidated, or unconsolidated. The variability may be random or found as strata of materials having different properties or containing different types or concentrations of constituents.

5.4.3.1 Geophysical survey methods may be used on piles to estimate physical homogeneity, which may or may not be related to chemical homogeneity, and to detect buried objects, both of which may need to be considered during the development of the sampling design and the safety plan for the investigation. The most suitable technique for detecting nonmetallic objects is electromagnetics. Ground-penetrating radar, a more sophisticated and complex technique, also may be considered. Electromagnetic techniques are suited particularly to large piles that contain leachate plumes (for example, mine tailings) or for the detection of large discontinuities in a pile (for example, different types of wastes or the transition from a disposal area to background soils). For metallic objects, metal detectors and magnetometers are useful and relatively easy to use in the field.

5.5 *Potential Investigation Errors*:

5.5.1 Equipment selection can bias sampling results even if the equipment is used properly. Bias can result from the incompatibility of the materials that the sampling equipment is made of with the materials being sampled. For example, the equipment could alter the characteristics of the sample. Some equipment will bias against the collection of certain particles sizes, and some equipment cannot penetrate the waste pile adequately.

5.5.2 Equipment, use, and operation can introduce error (bias) into the characterization of a waste pile. Sampling errors typically are caused when certain particle sizes are excluded, when a segment of the waste pile is not sampled, or when a location outside the pile is inadvertently sampled.

5.5.3 When stratification, layering, or solid phasing occurs it may be necessary to obtain and analyze samples of each of the distinct phases separately to minimize sampling bias. Care should be taken when sampling stratified layers to minimize cross contamination. Proper decontamination procedures should be used for all sampling equipment (see Practice D 5088).

5.5.4 Statistical bias includes situations where the data are not normally distributed or when the sampling strategy does not allow the potential for every portion of the pile to be sampled.

6. Sampling Strategy

6.1 Developing a strategy for sampling a waste pile requires a thorough examination of the site evaluation factors listed in Section 5. The location and frequency of sampling (number of samples) should be outlined clearly in the sampling plan, as well as provisions for the use of special sampling equipment, access of heavy equipment to all areas of the pile, if necessary, and so forth.

6.1.1 *Representative Sampling*—The collection of a representative set of samples from a waste pile typically will be complicated by the presence of a number of the site evaluation factors **(2,3)**.

6.1.2 *Heterogeneous Wastes*—Waste piles may be homogeneous, for applied purposes, or may be quite heterogeneous in particle size and contaminant distribution. If the particle sizes of the material in the waste pile and the distribution of contaminants are known, or can be estimated, then less sampling may be necessary to define the properties of interest in the waste pile. An estimate of the variability in contaminant distribution may be based on process knowledge or determined by preliminary sampling **(4)**. The more heterogeneous the waste pile is, the greater the planning and sampling requirements.

6.1.3 *Strata and Hot Spots*—A waste pile also could contain strata that have less internal variation in physical properties or concentrations of chemical constituents than the remainder of the waste pile **(2,5)**. For example, strata may be present in a waste pile due to changes in the process that generated the waste, or if different processes at a facility contribute waste to different parts of the waste pile. A stratified sampling strategy would consider this situation by conducting independent sampling of each stratum, which could reduce the number of samples required. These strata could be in specific areas of the waste pile **(4)**. Also, hot spots may be present in the waste pile that are unique in composition **(2,5)**.

6.2 *Specific Sampling Strategies*:

6.2.1 Although the most appropriate method for evaluating material in waste piles is to sample at or immediately following the point of generation (for example, conveyor belt), most sampling problems involve existing or in-place waste piles. Therefore, the following discussion will focus on in-place waste piles. Sampling strategies available for waste piles include directed or judgmental sampling, simple random sampling, stratified random sampling, systematic grid sampling, and systematic sampling over time **(2,6)**. General concerns about the collection of a representative sample, the existence of potential heterogeneity in the waste pile, the presence of strata within the waste pile, and the existence of distinct hot spots within the waste pile may also influence the selection of an appropriate sampling strategy and development of the sampling plan **(5)**. The following paragraphs provide an introduction to determining the appropriate number of samples to collect and the sampling strategies available for determining sample locations.

6.2.2 *Determining the Frequency or Number of Samples*—The frequency of sampling or the number of samples to collect typically will be based on several factors including the study objectives, properties of wastes in the pile, degree of confidence required, access to sampling points, and budgetary constraints. Practical guidance for determining the number of samples is included in Guide D 4687 and Refs **(2, 3)**.

6.2.3 *Directed Sampling*—Directed sampling (Fig. 1) is based on the judgment of the investigator and will not result necessarily in a sample that reflects the characteristics of the entire waste pile. Directed sampling also is called judgmental sampling, authoritative sampling, or nonprobability sampling. The experience of the investigator often is the basis for sample collection, and, depending on the study objectives, bias should be recognized as a potential problem. For preliminary screening investigations of a waste pile and for certain regulatory investigations, however, directed sampling may be appropriate. A directed sampling strategy could call for the collection of a composite sample from the surface area or the collection of discrete grabs at the surface of the pile (see Fig. 1). Directed sampling would typically focus on worst case conditions in a waste pile, for example, the most visually contaminated area or most recently generated waste.

6.2.4 *Simple Random Sampling*—Simple random sampling (Fig. 2) ensures that each element in the waste pile has an equal chance of being included in the sample **(2)**. This may be the method of choice when, for purposes of the investigation, the waste pile is randomly heterogeneous **(5)**. If the waste pile contains trends or patterns of contamination, a stratified random sampling or systematic grid sampling strategy would be more appropriate **(2)** (see 6.2.5 and 6.2.6).

6.2.4.1 A simple random approach could use a grid with random grids selected for sample collection (see Fig. 2). Note that the grid size could be selected based on the number of samples that are required (some guidance suggests having at least ten times the number of grids as samples required). Once the grid is overlaid and the sampling locations are selected, the decision must be made to collect either a discrete grab sample (surface), a composite of surface samples taken from predesignated locations within the grid cell (based on compass points), a vertical composite to a specified depth, or discrete

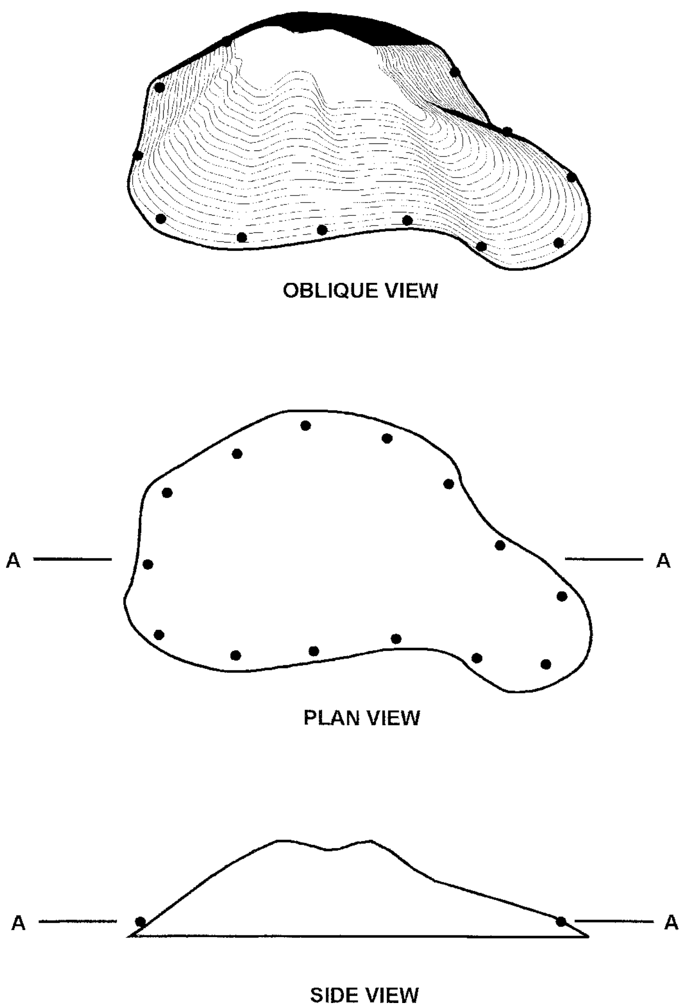


FIG. 1 Waste Pile Sampling Strategy—Directed Sampling

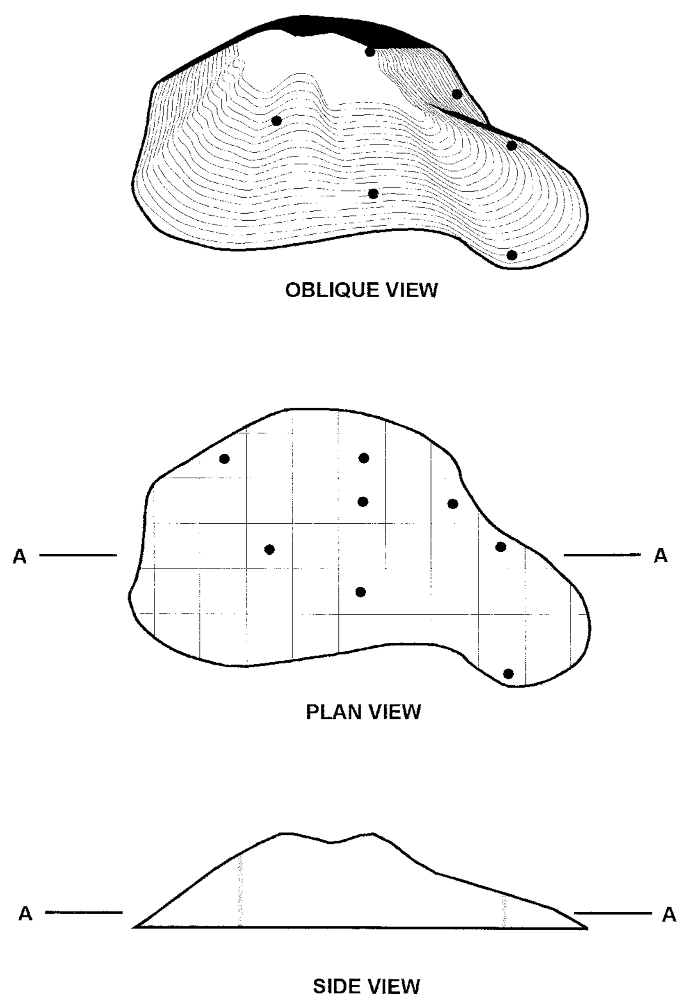


FIG. 2 Waste Pile Sampling Strategy—Simple Random Sampling

grab samples at specified depths. If discrete grab samples are desired at specified depths, they typically would be collected at the same location as the bore hole is advanced into the pile. Fig. 2 illustrates the collection of vertical composites at each of the randomly selected locations.

6.2.5 *Stratified Random Sampling*—Stratified random sampling (see Fig. 3) may be useful when distinct strata or homogeneous subgroups are identified within the waste pile **(2)**. The strata may be located in different areas of the pile or may be comprised of different layers (see Fig. 3). This approach is useful when the individual strata may be considered internally homogeneous or at least have less internal variation in what would otherwise be considered a heterogeneous waste pile **(2)**. Information on the waste pile usually is required to establish the location of individual strata unless process knowledge or changes in the composition of the material is obvious, such as with discoloration or with the type of waste. The grid may be utilized for sampling several horizontal layers if the strata are oriented horizontally **(4)**. A simple random sampling approach then is used within each stratum. The use of a stratified random sampling strategy may result in the collection of fewer samples. Fig. 3 illustrates a scenario where the number of samples collected in each stratum varies (plan view), and discrete grabs are collected in each boring at predesignated depths (side view).

6.2.6 *Systemic Grid Sampling*—Systematic grid sampling (see Fig. 4) involves the collection of samples at fixed intervals and is useful when the contamination is assumed to be distributed randomly **(2)**. This method also is commonly used with waste piles when estimating trends or patterns of contamination or when the objective is to locate hot spots. This approach may not be acceptable if the entire waste pile is not accessible or if the sampling grid locations become phased with variations in the distribution of contaminants within the waste pile **(6)**. It also may be useful for identifying the presence of strata within the pile. The grid and starting points should be laid out randomly over the waste pile, yet the method allows for rather easy location of exact sample locations by means of the grid (see Fig. 4). The same considerations discussed in 6.2.4 concerning the depth of each sample (surface, vertical composite, discrete grabs at depth) also should be considered. Fig. 4 illustrates the collection of vertical composites at each grid, which could be difficult and costly. Also note that the grid size typically would be adjusted according to the number of samples that are required.

6.2.7 *Systematic Sampling Over Time*—Systematic sampling over time at the point of generation is useful if the material is being sampled from a conveyor belt or being

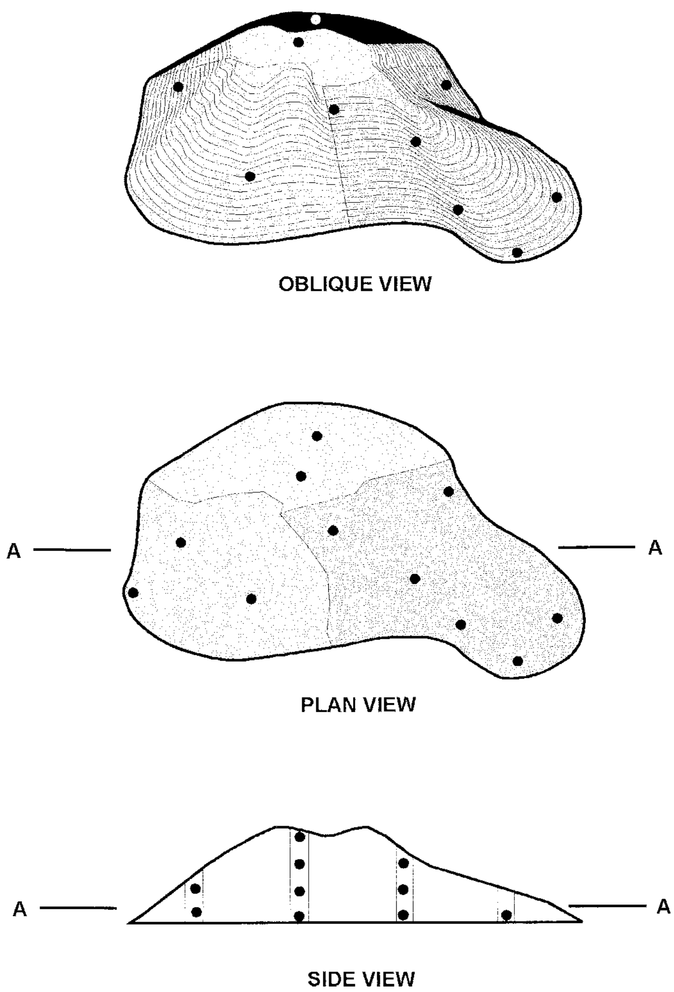


FIG. 3 Waste Pile Sampling Strategy—Stratified Random Sampling

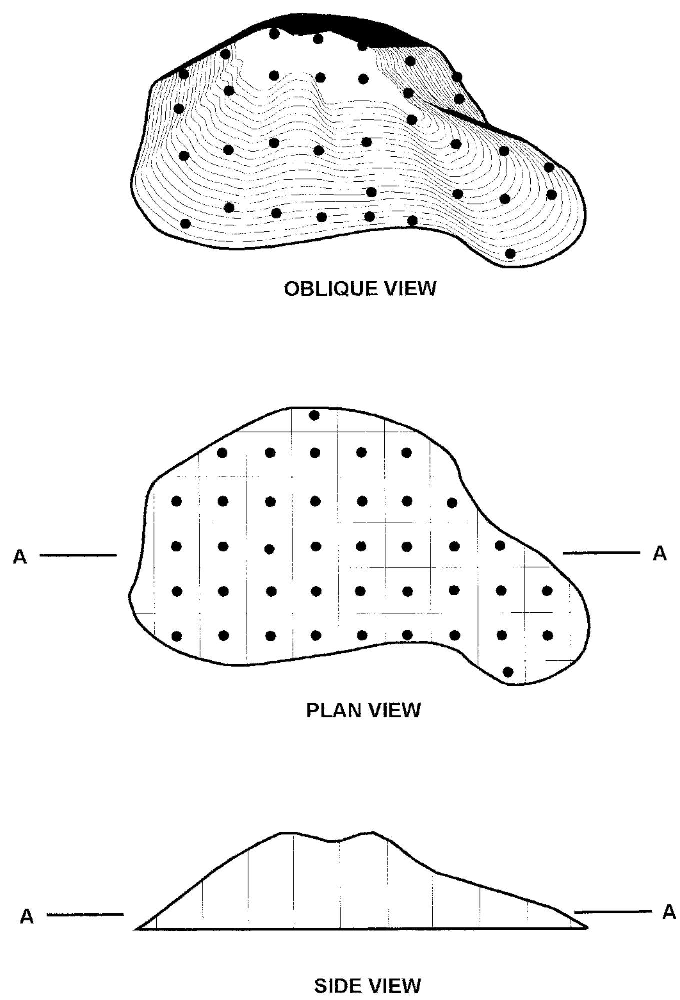


FIG. 4 Waste Pile Sampling Strategy—Systematic Grid Sampling

delivered by means of truck or pipeline to the waste pile. The sampling interval can be determined on a time basis, for example, every hour from a conveyor belt or pipeline discharge, or from every third truck load. The time between intervals is influenced by the factors addressed in 6.2.2.

6.2.8 *Alternative Approach*—In many cases, an objective of waste pile characterization is to determine the impact of the pile on the environment. At times this may be accomplished more easily by sampling the routes by which contaminants are dispersed from the pile than through direct sampling of the pile, especially for piles that are difficult to characterize. For example, ground water up-and-down gradient from the pile could be sampled to check for ground water contamination. The vadose zone below the pile also might be sampled to detect leachate (and potential ground water contamination) through soil sampling, vacuum lysimeters, or soil gas. Surface water and sediment in drainage channels down gradient from the pile also might be sampled. Surface soils, air samples, and contaminants deposited on vegetation can be used as indicators of atmospheric transport of contaminants from the pile, including both particulate and volatile materials. Such approaches will seldom replace pile sampling completely, but they may reduce the number of pile samples needed to make remedial action decisions (see Guide D 5730), also Refs **(7-9)**.

7. Selection of Sampling Equipment

7.1 Wastes in piles are often complex, multiphase mixtures of solids and semisolids. The wastes can range from powders to granules to large, heterogeneous solid fragments and can cover many acres in area. No single type of sampler can be used to collect representative samples of all types of waste from piles. Large, thick piles may require drill rigs to obtain samples from depth. The sampling of gases from within the pile requires other types of equipment. Table 2 lists typical waste types and the corresponding recommended samplers to use.

7.2 Sampling at depth from inside the pile may require heavy equipment designed for excavation or removal of soil or rock. Table 3 lists such equipment and its applications for sampling waste piles **(10)**.

7.3 Sampling equipment should be constructed of materials that are compatible with the waste to be sampled. Compatibility refers to the physical durability, lack of chemical reactivity with the waste, and lack of potential for contamination of the waste with analytes of concern. Typical materials of construction include stainless steel, plastic, and glass.

8. Data Use

8.1 The decisions that will be made based upon the data must be identified early in the planning process since these affect the approach to the problem and how the data will be evaluated. Decisions affecting waste classification, closure, and post-closure issues, are examples of the uses of the data. Methods to determine the volume of contaminated material in a pile or pile strata may be needed. Standard mathematical formulas for calculating the volume of a cone, cylinder, various prisms, and so forth, may be used.

8.2 *Statistical Considerations*:

8.2.1 Data quality assessment (DQA) methods are used to evaluate the data for any anomalies and to evaluate the assumptions for statistical evaluation. The statistician makes use of both subjective judgment (graphical analysis for identification of trends and anomalies) and statistical models and inference (for example, outlier detection, autocorrelation estimation) in the investigation of data for validity of the assumptions needed to make a statistical test. Classical statistical models assume that the samples collected from the population of interest are independent and have an identical probability distribution (that is, normal distribution with constant mean and variance). Random sampling is a method to ensure independence. The probability distributional assumptions are part of DQA that will determine if the classical statistical

TABLE 2 Sampling Devices Suitable for Waste Piles[A]

Location and Waste Type	Sampling Devices	ASTM Standard	Limitations
Subsurface			
Powdered, granular, or soil-like solids; sludges	split-barrel push coring device	D 1586 D 1587 D 4700 D 4823	Limited application for sampling moist and sticky solids, or particles with diameter 0.6 cm (0.25 in.) or more. Depth limitation of about 1 m.
	trier	D 5451	May not retain core sample of very dry granular materials. Not applicable to sampling solid wastes with particle diameter >½ the diameter of the sampling tube.
	auger	D 1452 D 4700	Does not collect undisturbed sample.
	thin-walled tube sampler	D 4823 D 4700	Collects relatively undisturbed core. Difficult to use on gravelly or rocky soils.
	drill rigs		Used for geoenvironmental exploration. To minimize sample contamination, avoid those using a water-based drilling fluid.
	soil gas samplers	D 5314	Used for volatile organic compounds.
Surface			
Powdered, granular, or soil-like solids; sludges	trowel or scoop	D 4700	Not applicable to sampling deeper than 8 cm (3 in.). Difficult to obtain reproducible mass of sample. May exclude certain particle sizes, especially large aggregates.
Slag	hammer/chisel Impact device		Changes particle size.

[A] This table is not all inclusive; other equipment may be used.

TABLE 3 Excavation and Removal Equipment for Waste Piles

Excavation and Removal Equipment	General Excavation	Ability to Excavate Hard and Compacted Material	Soil Hauling	Mixing of Solids, Soil	Spreading Cover	Site Maneuverability
Wheel or crawler Mounted backhoe	A[A]	A	B[B]/O[C]	A	A	A/B
Wheel or crawler Mounted front-end loader	A	A	A/B	A	A	A/B
Skid steer loader	A	B	B	A	B	A
Bulldozer	A	A	O	O	A	B

[A] A = Good choice. Equipment is fully capable of performing function listed.
[B] B = Secondary choice. Equipment is marginally capable of performing function listed.
[C] O = Not applicable or poor choice.

model is appropriate for the collected data. For directed sampling, the sampling is subjective and the sample results are typically judged on a qualitative basis.

8.2.2 Simple random sampling will provide an unbiased estimate of the average waste concentration, that is, an estimate of the mean. This unbiased estimate is independent of the geometry of the pile and of the distribution of the concentration of the contaminants, but it may not have the smallest variance. Other sampling designs, such as systematic grid sampling or stratified random sampling, may provide an average that has a smaller variance. If the waste pile has uneven topography, the calculation of the mean concentration of the pile should be a volume-weighted average, using core volume as the weighting factor to reduce the variance of the estimated mean.

8.2.2.1 For simple random sampling and systematic grid sampling designs, histogram and normal probability plots of the sample data can be used to judge if the data conform to normal distribution. If not, there are several alternatives. First, the classical statistical model may still be considered robust for the decision-making process. Second, a transformation of the data may approximate a normal distribution of the data. For example, logarithmic transformation will normalize data that are lognormal originally. If the data are lognormal, the question of whether to use the arithmetic mean or the geometric mean for decision-making purposes must be decided. Third, an alternative statistical model based on nonparametric methods, but which uses weaker assumptions, may be proposed to analyze the decision-making process. It may be advisable to consult a statistician.

8.2.2.2 For the stratified random sampling design, the test of normality is not straightforward. Generally, it requires a mathematical model to take out the strata effects first, then test for normality using the residuals. A statistician should be consulted.

8.2.2.3 In any of these cases, alternative consequences of the level of uncertainty can be calculated prior to collecting the data. These alternatives can be used by decision-makers to select the best strategy to minimize the environmental risks.

9. Keywords

9.1 piles; sampling; waste

APPENDIX

(Nonmandatory Information)

X1. WASTE PILE—A CASE HISTORY

X1.1 **Background**—The waste pile was generated by a facility that produces brass alloys from scrap metal. The byproduct from this operation was slag, which was generated in the recovery furnace. The slag was ground subsequently in a ball mill prior to being reintroduced into the recovery furnace. A large amount of the ground slag was disposed of in a waste pile which covered about one acre. No active management was occurring with the waste pile. No buried containers or extremely heterogenous material (unground slag) was suspected of being present in the waste pile based on facility records and interviews of personnel.

X1.1.1 Lead and cadmium were the constituents of concern based on process knowledge, and the possibility for the waste being hazardous was the regulatory consideration. The potential for off-site migration of contaminants was also an immediate concern, and this was considered in the development of the Phase 1 study design. Fig. X1.1 shows a site map of the facility and the slag pile. Fig. X1.2 shows a computer enhancement of the slag pile, and Fig. X1.3 shows a topographic view of the pile.

X1.2 Phase 1:

X1.2.1 *Objective*—The primary objective of the initial investigation was to determine if the slag in the waste pile classified as hazardous based on the concentration of lead and cadmium in a leach test. A secondary objective was to provide preliminary information on the potential migration and transport of contaminants from the waste pile off-site. The sampling plan for this initial investigation utilized a directed sampling strategy to provide a preliminary estimate of the lead concentration in the waste, the variability of contaminant concentrations in the pile, and the potential for leaching using the applicable leaching procedure mandated in regulations. Four composite samples were collected from the surface (0 to 15 cm or 0 to 6 in.) of the waste pile at locations within the four

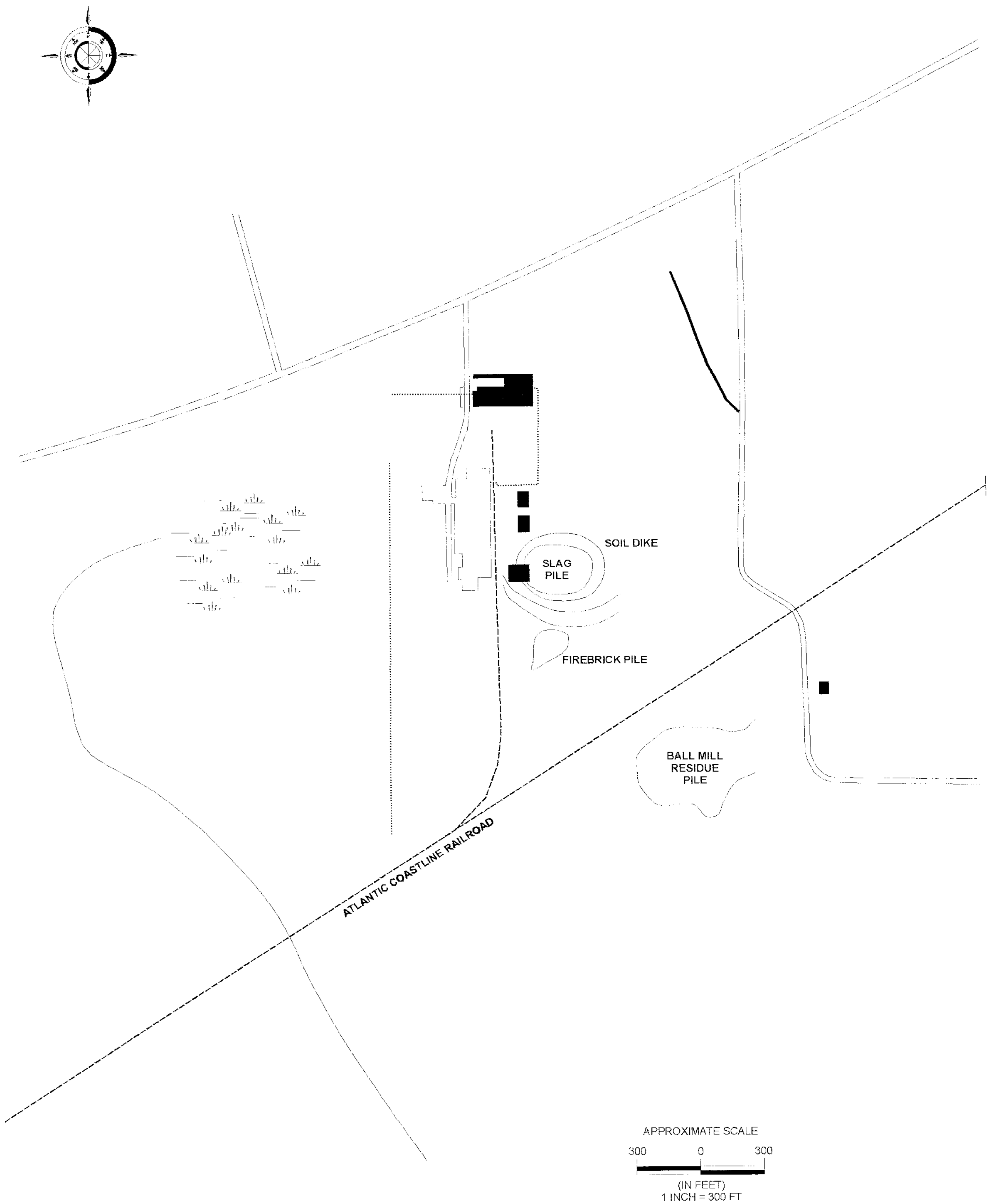


FIG. X1.1 Site Map

quadrants. The following environmental samples were also collected:

X1.2.1.1 Several soil samples in the vicinity of the waste pile,

X1.2.1.2 Sediment upstream and downstream in a stream which borders the facility,

X1.2.1.3 Sediment in a ditch which contained runoff from the pile, and

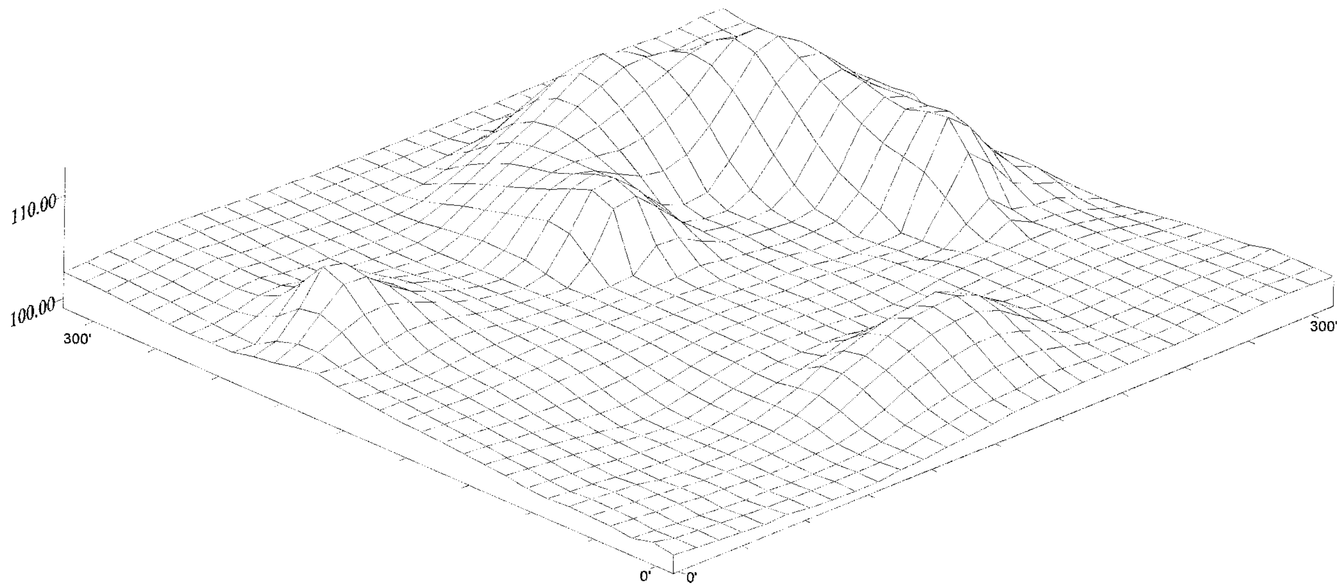


FIG. X1.2 Computer Enhancement of the Slag Pile (Front View) Scale 1:1:2

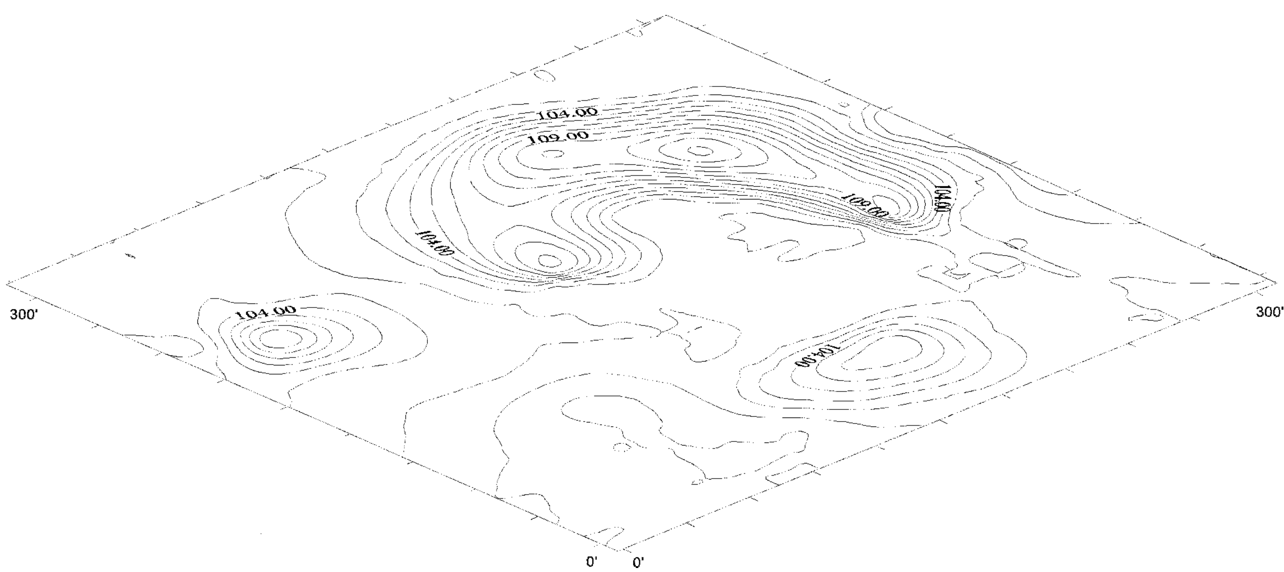


FIG. X1.3 Topographic View of the Slag Pile

X1.2.1.4 Two background soil samples.

X1.2.2 Fig. X1.4 shows the Phase 1 sampling locations within the slag pile, and Fig. X1.5 shows the same sampling locations on the topographic map of the pile.

X1.2.3 *Results*—Zinc, copper, cadmium, and lead were all elevated (compared to background) in the samples collected from the waste pile, and the concentrations did not appear to vary significantly between the samples. Since lead and cadmium are regulated constituents, a leach test was completed, and the lead results exceeded the regulatory level of 5 mg/L. Cadmium was just under the regulatory level of 1.0 mg/L. Lead and cadmium concentrations in the soil were 2 to 3 times above background, and the drainage ditch and downstream sediment sample also had elevated lead and cadmium levels.

X1.2.4 *Conclusion*— The waste pile contained slag that is hazardous for lead. The waste pile required further characterization to determine the variability in the pile. The presence of lead and cadmium in soils and the stream sediment downstream of the facility was confirmed and should be investigated further to determine the extent of contaminant transport.

X1.3 Phase 2:

X1.3.1 *Objective*—The objective is to characterize the waste pile further using a systematic grid sampling design. This design will delineate horizontal and vertical variability in lead and cadmium concentrations. The Phase 1 investigation also provided a good estimate of the anticipated variability in the waste pile. The number of samples required to characterize the waste pile adequately was calculated based on the average concentration, the anticipated variability, the regulatory level of concern, and the specified confidence interval. The grid size then was adjusted to accommodate the projection on the required number of samples. Composite samples were collected within each grid cell based on one center point and eight

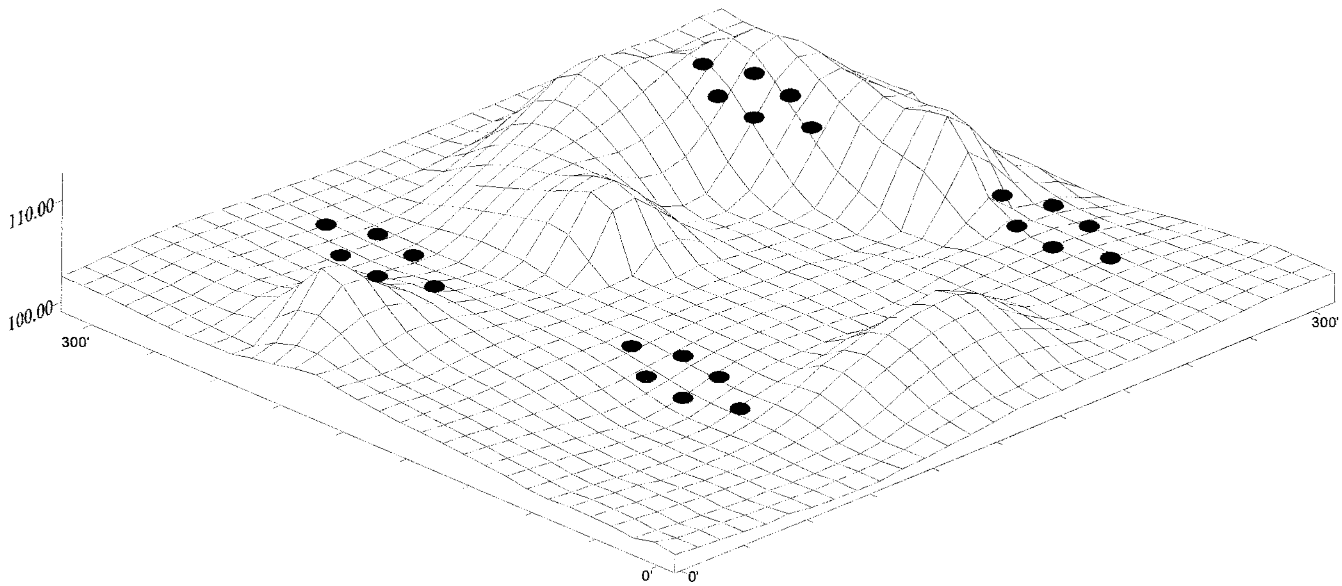


FIG. X1.4 Front View of the Slag Pile Showing Sampling Locations Scale 1:1:2

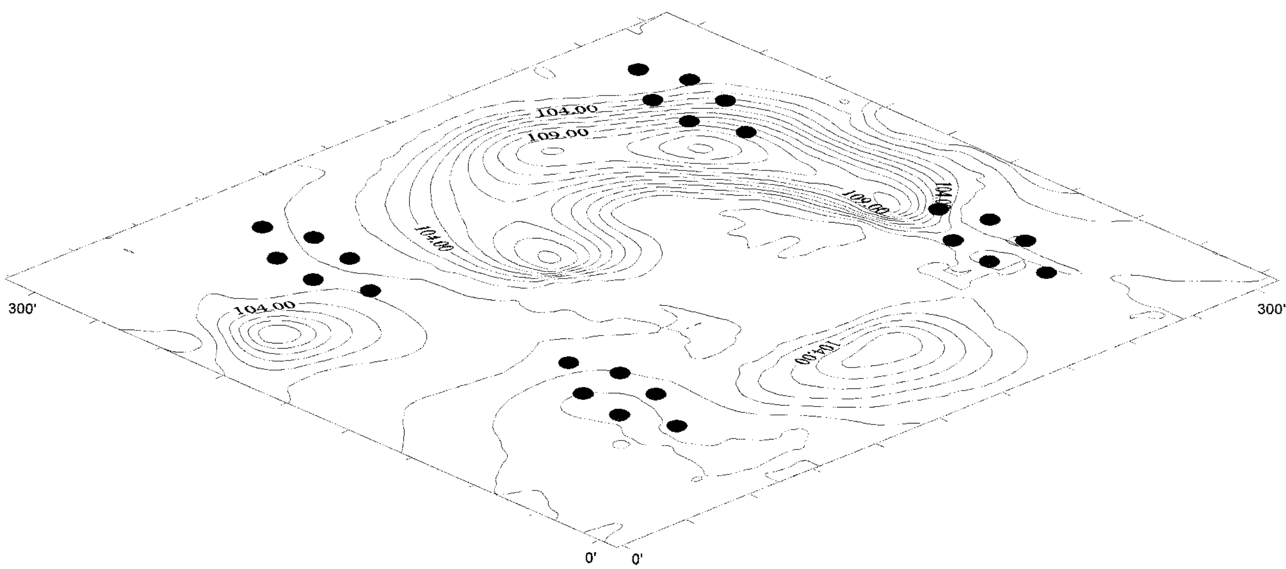


FIG. X1.5 Topographic View of the Slag Pile Showing Sampling Locations

points on the compass (45° intervals) equidistant from the center point. Ten percent of the grids were designated for vertical as well as surface (0 to 15 cm or 0 to 6 in.) sample collection. Additionally, 10 % of the grids were designated randomly for duplicate sampling (using a different aliquot pattern) to check the preliminary estimate on the variability. Additional environmental sampling was conducted but will not be covered in this discussion.

X1.3.2 *Results*—The results supported the initial Phase 1 investigation with lead consistently exceeding the regulatory level. Cadmium consistently was below the regulatory level.

X1.3.3 *Conclusion*— The waste pile was characteristic for lead and classified as hazardous according to the applicable regulations. There was no significant variability with depth, although several gradients were noticed across the grid based on lead concentration (scan) results.

X1.4 Phase 3:

X1.4.1 *Objective*—The objective is to determine thevolume of the waste pile in order to estimate both the disposal cost and the total amount of the civil penalty to be charged to the owner of the pile. The waste pile was surveyed using standard surveying techniques.

X1.4.2 *Results*—The results were used to calculate the volume using geometric principles. Also, a computer program was utilized which constructs contours based on the surveying information. The computer program was used as a check of the manual method, which produced a result that was 10 % higher in volume than the computer program.

X1.4.3 *Conclusion*— For penalty calculation purposes, the smaller estimate was utilized; however, the actual treatment and disposal costs could reflect the larger estimate.

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(**6**) U.S. Environmental Protection Agency (EPA), *Characterizing Heterogeneous Wastes: Methods and Recommendations*, EPA 600/R-92/033, (NTIS PB92-216894) February 1992. [Also published as hardback Smoley Edition: Rupp and Joens (1993).]

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(**8**) U.S. Environmental Protection Agency (EPA). *Guidance Document on the Statistical Analysis of Ground Water Monitoring Data at RCRA Facilities*, Office of Solid Waste, 1993.

(**9**) McCoy and Associates, Inc., "Soil Sampling and Analysis—Practices and Pitfalls," Hazardous Waste Consultant, Vol 10, No. 6, Lakewood, CO, 1992.

(**10**) PEI Associates, 1991, *Survey of Materials-Handling Technologies Used at Hazardous Waste Sites*, EPA 540/2-91/010, June 1991. (NTIS PB91-186924), 225 pp.

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Standard Guide for Representative Sampling for Management of Waste and Contaminated Media[1]

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1. Scope

1.1 This guide covers the definition of representativeness in environmental sampling, identifies sources that can affect representativeness (especially bias), and describes the attributes that a representative sample or a representative set of samples should possess. For convenience, the term" representative sample" is used in this guide to denote both a representative sample and a representative set of samples, unless otherwise qualified in the text.

1.2 This guide outlines a process by which a representative sample may be obtained from a population. The purpose of the representative sample is to provide information about a statistical parameter(s) (such as mean) of the population regarding some characteristic(s) (such as concentration) of its constituent(s) (such as lead). This process includes the following stages: (*1*) minimization of sampling bias and optimization of precision while taking the physical samples, (*2*) minimization of measurement bias and optimization of precision when analyzing the physical samples to obtain data, and (*3*) minimization of statistical bias when making inference from the sample data to the population. While both bias and precision are covered in this guide, major emphasis is given to bias reduction.

1.3 This guide describes the attributes of a representative sample and presents a general methodology for obtaining representative samples. It does not, however, provide specific or comprehensive sampling procedures. It is the user's responsibility to ensure that proper and adequate procedures are used.

1.4 The assessment of the representativeness of a sample is not covered in this guide since it is not possible to ever know the true value of the population.

1.5 Since the purpose of each sampling event is unique, this guide does not attempt to give a step by step account of how to develop a sampling design that results in the collection of representative samples.

1.6 Appendix X1 contains two case studies, which discuss the factors for obtaining representative samples.

1.7 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*

D 3370 Practices for Sampling Water from Closed Conduits[2]
D 4448 Guide for Sampling Groundwater Monitoring Wells[3]
D 4547 Practice for Sampling Waste and Soils for Volatile Organics[3]
D 4700 Guide for Soil Sampling from the Vadose Zone[4]
D 4823 Guide for Core-Sampling Submerged, Unconsolidated Sediments[5]
D 5088 Practice for Decontamination of Field Equipment Used at Nonradioactive Waste Sites[6]
D 5792 Practice for Generation of Environmental Data Related to Waste Management Activities: Development of Data Quality Objectives[3]
D 5956 Guide for Sampling Strategies for Heterogeneous Wastes[3]
D 6051 Guide for Composite Sampling and Field Subsampling for Environmental Waste Management Activities[3]

3. Terminology

3.1 *analytical unit, n*—the actual amount of the sample material analyzed in the laboratory.

3.2 *bias, n*—a systematic positive or negative deviation of the sample or estimated value from the true population value.

3.2.1 *Discussion*—This guide discusses three sources of bias—sampling bias, measurement bias, and statistical bias.

There is a sampling bias when the value inherent in the physical samples is systematically different from what is inherent in the population.

There is a measurement bias when the measurement process produces a sample value systematically different from that inherent in the sample itself, although the physical sample is

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[2] *Annual Book of ASTM Standards*, Vol 11.01.
[3] *Annual Book of ASTM Standards*, Vol 11.04.
[4] *Annual Book of ASTM Standards*, Vol 04.08.
[5] *Annual Book of ASTM Standards*, Vol 11.02.
[6] *Annual Book of ASTM Standards*, Vol 04.09.

itself unbiased. Measurement bias can also include any systematic difference between the original sample and the sample analyzed, when the analyzed sample may have been altered due to improper procedures such as improper sample preservation or preparation, or both.

There is a statistical bias when, in the absence of sampling bias and measurement bias, the statistical procedure produces a biased estimate of the population value.

Sampling bias is considered the most important factor affecting inference from the samples to the population.

3.3 *biased sampling, n*—the taking of a sample(s) with prior knowledge that the sampling result will be biased relative to the true value of the population.

3.3.1 *Discussion*—This is the taking of a sample(s) based on available information or knowledge, especially in terms of visible signs or knowledge of contamination. This kind of sampling is used to detect the presence of localized contamination or to identify the source of a contamination. The sampling results are not intended for generalization to the entire population. This is one form of authoritative sampling (see *judgment sampling*.)

3.4 *characteristic, n*—a property of items in a sample or population that can be measured, counted, or otherwise observed, such as viscosity, flash point, or concentration.

3.5 *composite sample, n*—a combination of two or more samples.

3.6 *constituent, n*— an element, component, or ingredient of the population.

3.6.1 *Discussion*—If a population contains several contaminants (such as acetone, lead, and chromium), these contaminants are called the constituents of the population.

3.7 *Data Quality Objectives, DQOs, n*—qualitative and quantitative statements derived from a DQO process describing the decision rules and the uncertainties of the decision(s) within the context of the problem(s) (see Practice D 5792).

3.8 *Data Quality Objective Process*—a quality management tool based on the Scientific Method and developed by the U.S. Environmental Protection Agency to facilitate the planning of environmental data collection activities. The DQO process enables planners to focus their planning efforts by specifying the use of data (the decision), the decision criteria (action level), and the decision maker's acceptable decision error rates. The products of the DQO process are the DQOs (see Practice D 5792).

3.9 *error, n*—the random or systematic deviation of the observed sample value from its true value (see *bias* and *sampling error*).

3.10 *heterogeneity, n*— the condition or degree of the population under which all items of the population are not identical with respect to the characteristic(s) of interest.

3.10.1 *Discussion*—Although the ultimate interest is in the statistical parameter such as the mean concentration of a constituent of the population, heterogeneity relates to the presence of differences in the characteristics (for example, concentration) of the units in the population. It is due to the presence of fundamental heterogeneity (or fundamental error)[7] in the population that sampling variance arises. Degree of sampling variance defines the degree of precision in estimating the population parameter using the sample data. The smaller the sampling variance is, the more precise the estimate is. See also *sampling error*.

3.11 *homogeneity, n*— the condition of the population under which all items of the population are identical with respect to the characteristic(s) of interest.

3.12 *judgment sampling, n*—taking of a sample(s) based on judgment that it will more or less represent the average condition of the population.

3.12.1 *Discussion*—The sampling location(s) is selected because it is judged to be representative of the average condition of the population. It can be effective when the population is relatively homogeneous or when the professional judgment is good. It may or may not introduce bias. It is a useful sampling approach when precision is not a concern. This is one form of authoritative sampling (see *biased sampling*.)

3.13 *population, n*— the totality of items or units of materials under consideration.

3.14 *representative sample, n*—a sample collected in such a manner that it reflects one or more characteristics of interest (as defined by the project objectives) of a population from which it is collected.

3.14.1 *Discussion*—A representative sample can be a single sample, a collection of samples, or one or more composite samples. A single sample can be representative only when the population is highly homogeneous.

3.15 *representative sampling, n*—the process of obtaining a representative sample or a representative set of samples.

3.16 *representative set of samples, n*—a set of samples that collectively reflect one or more characteristics of interest of a population from which they were collected. See *representative sample*.

3.17 *sample, n*—a portion of material that is taken for testing or for record purposes.

3.17.1 *Discussion*—Sample is a term with numerous meanings. The scientist collecting physical samples (for example, from a landfill, drum, or monitoring well) or analyzing samples considers a sample to be that unit of the population that was collected and placed in a container. A statistician considers a sample to be a subset of the population, and this subset may consist of one or more physical samples. To minimize confusion, the term *sample*, as used in this guide, is a reference to either a physical sample held in a sample container, or that portion of the population that is subjected to in situ measurements, or a set of physical samples. See *representative sample*.

3.17.1.1 The term *sample size* also means different things to the scientist and the statistician. To avoid confusion, terms such as sample mass/sample volume and number of samples are used instead of sample size.

3.18 *sampling error*— the systematic and random deviations of the sample value from that of the population. The

[7] Pitard, F. F., "*Pierre Gy's Sampling Theory and Sampling Practice: Heterogeneity, Sampling Correctness and Statistical Process Control,*" 2nd ed., CRC Press Publishers, 1993.

systematic error is the *sampling bias*. The random error is the *sampling variance*.

3.18.1 *Discussion*—Before the physical samples are taken, potential sampling variance comes from the inherent population heterogeneity (sometimes called the "fundamental error," see *heterogeneity*). In the physical sampling stage, additional contributors to sampling variance include random errors in collecting the samples. After the samples are collected, another contributor is the random error in the measurement process. In each of these stages, systematic errors can occur as well, but they are the sources of bias, not sampling variance.

3.18.1.1 Sampling variance is often used to refer to the total variance from the various sources.

3.19 *stratum, n*—a subgroup of the population separated in space or time, or both, from the remainder of the population, being internally similar with respect to a target characteristic of interest, and different from adjacent strata of the population.

3.19.1 *Discussion*—A landfill may display spatially separated strata, such as old cells containing different wastes than new cells. A waste pipe may discharge into temporally separated strata of different constituents or concentrations, or both, if night-shift production varies from the day shift. In this guide, strata refer mostly to the stratification in the concentrations of the same constituent(s).

3.20 *subsample, n*— a portion of the original sample that is taken for testing or for record purposes.

4. Significance and Use

4.1 Representative samples are defined in the context of the study objectives.

4.2 This guide defines the meaning of a representative sample, as well as the attributes the sample(s) needs to have in order to provide a valid inference from the sample data to the population.

4.3 This guide also provides a process to identify the sources of error (both systematic and random) so that an effort can be made to control or minimize these errors. These sources include sampling error, measurement error, and statistical bias.

4.4 When the objective is limited to the taking of a representative (physical) sample or a representative set of (physical) samples, only potential sampling errors need to be considered. When the objective is to make an inference from the sample data to the population, additional measurement error and statistical bias need to be considered.

4.5 This guide does not apply to the cases where the taking of a nonrepresentative sample(s) is prescribed by the study objective. In that case, sampling approaches such as judgment sampling or biased sampling can be taken. These approaches are not within the scope of this guide.

4.6 Following this guide does not guarantee that representative samples will be obtained. But failure to follow this guide will likely result in obtaining sample data that are either biased or imprecise, or both. Following this guide should increase the level of confidence in making the inference from the sample data to the population.

4.7 This guide can be used in conjunction with the DQO process (see Practice D 5792).

4.8 This guide is intended for those who manage, design, and implement sampling and analytical plans for waste management and contaminated media.

5. Representative Samples

5.1 Samples are taken to infer about some statistical parameter(s) of the population regarding some characteristic(s) of its constituent(s) of interest. This is discussed in the following sections.

5.2 *Samples*—When a representative sample consists of a single physical sample, it is a sample that by itself reflects the characteristics of interest of the population. On the other hand, when a representative sample consists of a set of physical samples, the samples collectively reflect some characteristics of the population, though the samples individually may not be representative. In most cases, more than one physical sample is necessary to characterize the population, because the population in environmental sampling is usually heterogeneous.

5.3 *Constituents and Characteristics*—A population can possess many constituents, each with many characteristics. Usually it is only a subset of these constituents and characteristics that are of interest in the context of the stated problem. Therefore, samples need to be representative of the population only in terms of these constituent(s) and characteristic(s) of interest. A sampling plan needs to be designed accordingly.

5.4 *Parameters*—Similarly, samples need to be representative of the population only in the parameter(s) of interest. If the interest is only in estimating a parameter such as the population mean, then composite samples, when taken correctly, will not be biased and therefore constitute a representative sample (regarding bias) for that parameter. On the other hand, if the interest happens to be the estimation of the population variance (of individual sampling units), another parameter, then the variance of the composite samples is a biased estimate of the population variance and therefore is not representative. (It is to be noted that composite samples are often used to increase the precision in estimating the population mean and not to estimate the population variance of individual sampling units.)

5.5 *Population*—Since the samples are intended to be representative of a population, a population must be well defined, especially in its spatial or temporal boundaries, or both, according to the study objective.

5.6 *Representativeness*—The word "reflects" in this guide is used to mean a certain degree of low bias and high precision when comparing the sample value(s) to the population value(s). This is a broad definition of sample representativeness used in this guide. A narrower definition of representativeness is often used to mean simply the absence of bias.

5.6.1 *Bias*—Bias is sometimes mistakenly taken to be "a difference between the observed value of a physical sample and the true population value." The correct definition of bias is "a *systematic* (or consistent) difference between an observed (sample) value and the true population value." The word "systematic" here implies "on the average" over a set of physical samples, and not a single physical sample. Recall that sampling error consists of the random and systematic deviations of a sample (or estimated) value from that of the population. Although random deviations may occur on occasions due to imprecision in the sampling or measurement processes, or both, they balance out on the average and lead to no systematic difference between the sample (or estimated) value and the population value. The random deviation corresponds to the observation of "a random difference between a single physical sample value and the true population value," which can be randomly positive or negative, and is not a bias. On the other hand, a persistent positive or negative difference is a systematic error and is a bias.

5.6.1.1 In order to assess bias, the true population value must be known. Since the true population value is rarely known, bias cannot be quantitatively assessed. However, this guide provides an approach to identifying the potential sources of bias and general considerations for controlling or minimizing these potential biases.

5.6.2 *Precision*—Precision has to do with the level of confidence in estimating the population value using the sample data. If the population is totally homogeneous and the measurement process is flawless, a single sample will provide a completely precise estimate of the population value. When the population is heterogeneous or the measurement process is not totally precise, or both, a larger number of samples will provide a more precise estimate than a smaller number of samples.

5.6.2.1 In the case of bias, the goal in environmental sampling is its absence. In the case of precision, the goal in sampling will depend on factors such as:

(1) The precision level needed to achieve the desired levels of decision errors, both false positive and false negative errors,

(2) If the true value is known or suspected to be well below the regulatory limit, high precision in the samples may not be needed, and

(3) The study budget.

5.6.2.2 Note that the second item applies similarly to bias as well.

5.6.2.3 Since bias, especially during sampling, can be very large when proper procedures are not followed, it is considered to be the first necessary condition for sample representativeness. On the other hand, precision can be more or less controlled, for example, by increasing the number of samples taken or by decreasing the sampling or measurement variabilities, or both.

5.6.2.4 The optimal number of samples to take to achieve a desired level of precision is typically an issue in optimization of a sampling plan. Therefore, the precision issue will be covered only briefly in this guide.

6. A Systematic Approach to Representative Sampling

6.1 A systematic approach is one that first defines the desired end result and then designs a process by which such a result can be obtained. In representative sampling, the desired end result is a sample or a set of samples that achieves desired levels of low bias and high precision.

6.2 A representative sampling process is described in Fig. 1. The key components in the process are described in this section.

6.3 *Study Objective*— A sampling plan is designed according to a defined problem or a stated study objective. The samples are then collected according to the sampling plan. Generally, the study objective dictates that representative samples be taken for the purpose of inference about the population. In that case, these samples will need to be collected according to this guide in order for the inference to be valid.

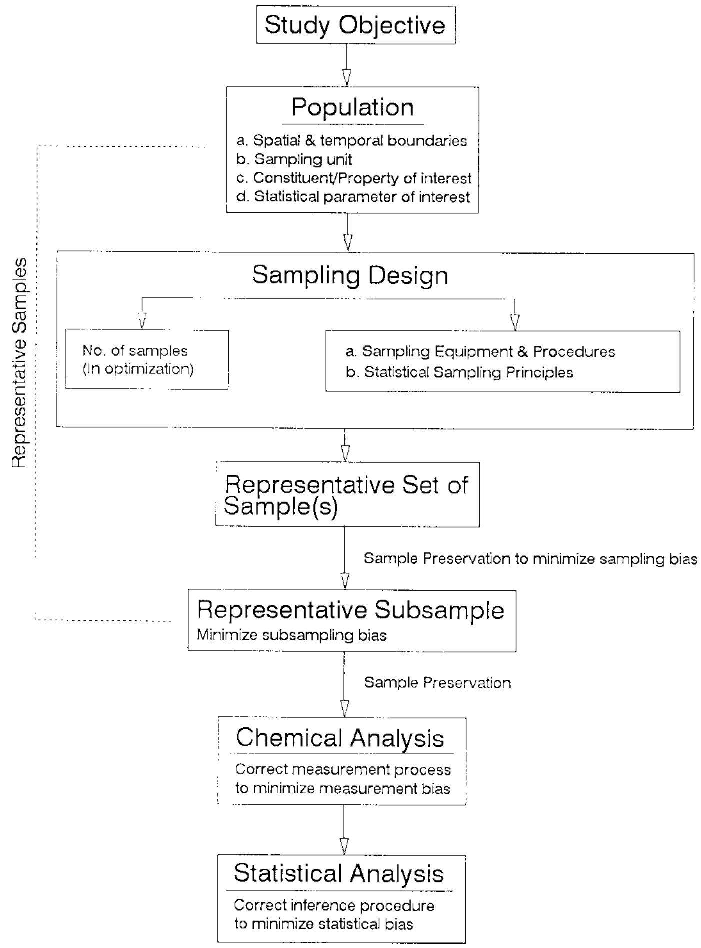

FIG. 1 A Systematic Approach to Representative Sampling

Occasionally, the objective is merely to detect the presence of a contaminant or to obtain a "worst case" sample. In that case, an authoritative sampling approach (biased sampling or judgment sampling) may be taken and this guide does not apply.

6.4 *Population*—A population consists of the totality of items or units of materials under consideration (Compilation of ASTM Standard Definitions, 1990). Its boundaries (spatial or temporal, or both) are defined according to the problem statement. This population is usually called the *target population*. In order to solve the stated problem, samples must be taken from the target population.

6.4.1 *Sampled Population*—Sometimes some parts of the target population may not be amenable to sampling due to factors such as accessibility. The boundaries of the target population actually sampled due to factors such as incomplete accessibility define the sampled population.

6.4.1.1 Although the samples taken from the sampled population may be representative of the sampled population, they may not be representative of the target population. In this case, potential exists that the samples taken from the sampled population may systematically deviate from the true value of the target population, thereby introducing bias when making inference from the samples to the target population.

6.4.1.2 When the boundaries of the target and sampled populations are not identical, some possible solutions are:

(1) The parties to the decision-making may agree that the

sampled population is a sufficient approximation to the target population. A sampling plan can then be designed to take representative samples from the" sampled population,"

(2) Qualifications on the sampling results are made based on the differences between the two populations. Some professional judgment may have to be exercised here, and

(3) Redefine the problem by considering what problem is solvable based on the observed differences between the two populations.

6.4.1.3 Occasionally, the sampled population is chosen on purpose to be different from the target population. For example, an investigator may be interested in the lead content in the sludge of a surface impoundment (the target population). He may decide to take samples from the sludge near the inlet (sampled population). Thus, the impoundment is the target population, while the inlet area is the sampled population. If the interest is in the target population, then this is an example of a biased sampling approach. On the other hand, the involved parties may decide to redefine the target population to include only the inlet area. Then the target population and the sampled population are identical. Again, the definition of a population depends on the problem statement.

6.4.1.4 In yet other circumstances, an investigator may take only a sample from the population. The following cases are possible:

(1) This one physical sample can be a sample from a biased sampling approach, for the purpose of detecting the presence of a contaminant or identifying the source of contamination. Therefore, it is not a representative sample due to its bias,

(2) This one physical sample can be a sample from judgment sampling, for the purpose of estimating the average condition of the population. Bias may or may not exist depending to some degree on the expertise of the sampler,

(3) This sample can be viewed as a population itself if the investigator is interested in the sample alone and a result from this sample is not to be used to infer to areas outside the sample. In this case, no bias exists, and

(4) If this sample is the composite of a few samples taken from the population, bias is likely to be minimal if the original samples are carefully taken.

6.4.2 *Decision Unit*— Often a population may be divided into several exposure units, cleanup units, or strata. If the environmental management decision is to be made for the entire population as a whole, representative samples can be obtained by designs such as a stratified random sampling design. Here the entire population is the decision unit. On the other hand, if the decision is to be made on each unit or stratum, then each unit or stratum is the decision unit. In this case, representative sample(s) need to be taken from each unit or stratum as if the unit or stratum is the population.

6.4.2.1 If the units or strata are relatively small in size or too numerous to take many samples per unit or stratum, composite sample(s) can be taken from each unit or stratum to increase precision without introducing bias. Alternatively, if precision is not a concern and there is sufficient professional expertise to avoid bias, a judgment sample(s) can be taken from each unit or stratum.

6.4.3 *Heterogeneity*— Heterogeneity is discussed in greater detail in Guide D 5956.

6.4.3.1 The degree and extent of population heterogeneity affect potential bias and precision in the samples. Population heterogeneity can be viewed at least in three different ways:

(1) When the population is heterogeneous in a random manner in only the distribution of the concentration, but not in the physical materials such as particle sizes, designs such as a simple random sampling design will generally produce samples with minimal bias. Its precision will then depend on the number of samples taken,

(2) When the population is randomly heterogeneous in concentrations due to large differences in the materials such as particle size, a simple random sampling design may still be effective if the sample volume/weight and sampling equipment are chosen to accommodate the largest particles and thereby prevent introduction of bias, and

(3) If the population is systematically heterogeneous, such as the presence of stratification in concentrations, then a simple random sampling design may not be biased, but will be less precise than an alternative design such as stratified random sampling.

6.4.3.2 Heterogeneity in the population affects the sampling variance. Sampling variance is a function of factors such as the population heterogeneity and the sample volume or weight. It is clear that the more heterogeneous the population is, the larger the inherent sampling variance is. It is also clear that samples of smaller volume or weight will have a higher sampling variance than those with greater volume or weight. However, the reduction in sampling variance due to increased volume or weight may eventually reach a limit. Determination of the optimal sample volume or weight is beyond the scope of this guide.[7]

6.4.3.3 The proper procedure is to first determine the right sample volume or weight, then to determine the number of samples needed for the chosen sample volume or weight.

6.4.3.4 Since stratification as a phenomenon of population heterogeneity is fairly common, it is discussed in greater details as follows.

6.4.4 *Stratification*— There are generally three types of stratification affecting sample representativeness. One is a stratification in the distribution of the contaminant concentration distribution alone. The second is a stratification in sampling materials or matrices alone. The third is a combination of both types. Stratification of any type is not a big problem regarding sample representativeness if each stratum is a decision unit. In that case, the units in a stratum are by definition relatively similar, apart from the random variations in concentrations. A simple random sampling design can be used to obtain representative samples (unbiased) for each stratum. The question of sample representativeness becomes more complicated when a decision is to be made over all the strata in the population.

6.4.4.1 *A Single Representative Sample in A Stratified Population*—When the objective is to obtain a single (physical) representative sample of all the strata, the sample must be a composite of individual samples from the strata (for example, at least one individual sample per stratum). Here the volumes or weights of the individual samples should be proportional to the relative stratum sizes. The composite sample so obtained would be unbiased. However, since there is only one composite sample, precision of the composite sample cannot be estimated. If there are existing data on the precision of the individual samples in the strata, then the precision of the composite sample can be inferred from the precision of the individual samples by theoretical or empirical relationship. See Guide D 6051.

6.4.4.2 *A Representative Set of Samples*—When the population is stratified, a set of samples obtained by statistical designs such as stratified random sampling, where the number of samples to be taken from the strata are proportional to the relative sizes of the strata, is unbiased and more precise than a set of samples taken without considering the stratification.

6.4.5 *Parameter(s) of Interest*—This refers to the statistical parameter such as mean or variance of the population. It is often used with a characteristic such as concentration of a constituent(s) of the population. An example is the mean (parameter) concentration (characteristic) of lead (constituent). Another example is a population of mixture of silt-size calcium carbonate particles and large cobble-size particles of calcium carbonate. The interest here could be in the mean (parameter) particle size or chemical composition (characteristic) of calcium carbonate (constituent), depending on the study objective.

6.5 *Develop A Sampling Design*—The objectives of a sampling design are to minimize bias and achieve a desired level of precision. Precision and bias are an issue at various stages of the process of inferring from the samples to the population. The first stage is the act of obtaining the physical samples. The second stage is the act of analyzing the physical samples and translating them into data. The third stage is the use of statistical method to infer from the sample data to the population. At the first stage, the main concerns are sampling precision and bias. At the second stage, the concerns are measurement of precision and bias. At the third stage, the concern is statistical bias.

6.5.1 At the first stage of obtaining physical samples, the issues of precision and bias are sometimes grouped together as sampling design issues.

6.5.2 Bias at this stage is often called the sampling bias. Sampling bias is the systematic difference between the value inherent in the physical samples and the true population value. The word "inherent" is used because at this point the physical samples have not been translated into data.

6.5.3 The phrase "systematic difference" implies a persistent difference in long-term average or expectation, not the occasional random difference. Representative samples, apart from the issue of precision, are obtained when this long-term expected difference is zero or nearly so.

6.5.4 Since the true population value is typically not known, sampling bias cannot be assessed. However, efforts to minimize sampling bias can be attempted in at least two areas:

6.5.4.1 *Proper Statistical Sampling Design*—Statistical sampling design has to do with where and how samples are to be taken, where equal probability of selecting any of the units or items in the population is often a primary requirement. If the probability of selection is not equal, it is highly likely that bias will have been introduced into the physical samples so obtained. Depending on the layout of the population, designs such as simple random sampling or stratified random sampling can be used.

6.5.4.2 *Proper Sampling Procedures and Sampling Equipment*—This includes proper procedures for compositing, subsampling, sample preparation and preservation, and proper use of the chosen sampling equipment. This is a major source affecting precision and bias, especially bias.

6.5.5 In the case of precision, it can be controlled by things such as the number of samples taken, the use of composite samples, or more precise sampling techniques. Often, the number of samples to take is considered the key design issue. Some considerations regarding precision are:

6.5.5.1 If a population is relatively small compared to the sample mass/volume and the distribution of the characteristic of interest is random, it may be appropriate to collect a smaller number of samples by a random or systematic sampling approach, and

6.5.5.2 If a population is relatively large compared to sample mass/volume and the characteristic of interest is not randomly distributed (for example, stratified), a greater number of samples and a stratified sampling approach may be needed.

6.5.6 *Compositing*— Compositing is the combination of two or more individual physical samples into a single sample. It is often used to reduce the analytical costs, while maintaining or increasing precision relative to the individual samples (see Guide D 6051). Bias may or may not be introduced in compositing, depending on the study objective and the physical means of compositing. For example:

6.5.6.1 If the study calls for the estimation of the population variance (or standard deviation) of individual samples, then composite samples will surely underestimate the population variance, and

6.5.6.2 If the physical means of compositing changes the characteristics of the samples, then bias may have been introduced (unless such changes are part of the study design).

6.6 *Subsampling*— Sampling bias can be introduced in subsampling unless the same proper sampling protocol is followed as in taking samples from the original population.

6.6.1 *Discussion*—After the physical samples have been obtained and before they are measured, bias can be prevented by following proper sample preservation and preparation procedures. It is not important whether these procedures are viewed as part of the sampling process or as part of the measurement process. It is only important in following the proper procedures to prevent bias.

6.7 *Measurement of Precision and Bias*:

6.7.1 The measurement process, like the sampling process, also consists of a random error and a systematic error. The random errors define the degree of measurement precision, and the systematic error defines the degree of measurement bias.

6.7.2 Like sampling precision, measurement precision is controlled by things such as the number of replicate analyses performed per sample and refinements of the analytical method.

6.7.3 Measurement bias is a systematic difference between the sample value produced by the measurement process and the true population value, assuming that the physical samples are unbiased before the analysis. The bias can come from contamination, loss or alteration of the sample materials, systematic errors in the measurement device, or from systematic human errors.

6.7.4 Often the measurement bias can be reasonably estimated in a laboratory testing setting when the true value is known. Laboratory samples spiked with known quantities of a chemical or certified reference standard can often be used to assess potential measurement bias. Minimization or adjustment for such estimable bias in the measurement process is essential in order to obtain data that are unbiased. When estimation of bias is not possible, care in measurement protocol and training is probably the only recourse.

6.7.4.1 *Discussion*—It is important to note that, when inferring from the sample data to the population, all the sources of imprecision, including sampling, subsampling, and measurement, need to be combined. The process of accumulating these sources of variation is sometimes called the "propagation of errors." The determination of the optimal numbers of samples, subsamples, and replicates are an issue of optimization and is not covered in this guide.

6.8 *Statistical Bias*— Statistical bias can result from an inappropriate sampling design or inappropriate estimation procedures, or both:

6.8.1 *Selection Bias from Sampling Design*—In the course of taking the sample, if the population units do not have the same probability of being selected, bias can be introduced. This bias can be prevented or minimized when a statistical sampling design is carefully selected, based on the study objective and the layout of the population. Some possible designs are the simple random sampling design and the stratified random sampling design.

6.8.2 *Estimation of Bias from Estimation Procedures*—This bias occurs when the expected value of the statistical estimator does not equal the true value.

6.8.2.1 Estimation bias can occur when the wrong statistical distribution of the data is used. For example, if the normal distribution assumption is used when the true data distribution is lognormal, the interval estimate of the mean concentration will be an biased estimate against the true interval. Thus, the expected value of the estimator will not be equal to the true value. To avoid this potential bias, it is wise to check the data distribution.

6.8.2.2 Estimation bias can also occur when a wrong statistical estimator is used. For example, if the sum of squares of deviations from the sample mean divided by the number of samples (that is, $\Sigma_{i=1,n} (x_i - \bar{x})^2/n$) is used to estimate the population variance, then this estimator is biased (its mathematical expected value is not equal to the population variance). If its denominator is modified to be ($n - 1$), then it is an unbiased estimator. For an unbiased statistical estimator, the reader is advised to check with a statistician.

7. Attributes of Representative Samples

7.1 The attributes of a representative (physical) sample or a representative set of (physical) samples can be described in the chronological order in which samples are taken. Note that these attributes apply only to how representative the physical samples are of the population. This corresponds to the upper half of Fig. 1.

7.2 *Design Considerations*:

7.2.1 A well-defined target population. The target population includes all the population units as determined from the stated problem.

7.2.2 The sampled population equals the target population in their spatial or temporal boundaries, or both. The sampled population consists of the population units directly available for measurement.[8]

7.2.2.1 When all the population units in the target population are accessible and directly available for measurement, then the sampled population is identical to the target population in its spatial or temporal boundaries, or both.

7.2.2.2 When not all the population units are directly available for measurement, then the inference from the sample is made to the sampled population, not the target population.

7.2.3 Size (weight or volume) of the sampling unit is well defined.

7.2.3.1 The population can be divided into various sizes (weight or volume) of population units. The size of the sampling unit is the size of the population unit most appropriate for the sampling purposes.

7.2.3.2 The appropriate size of the sample is determined by degree of heterogeneity of the materials to be sampled, such as particle size or shape.

7.3 *Sampling and Measurement Considerations*:

7.3.1 Correct sampling procedures are followed to minimize sampling bias.

7.3.1.1 Absence or minimization of bias is a key attribute of representative samples. Sampling bias can be minimized by following correct sampling procedures. Correct sampling procedures have two components.

(1) A sampling procedure that maximizes the potential of population units having equal probability of selection as sampled, and

(2) Correct sampling procedures. This includes the selection of appropriate equipment and proper use of that equipment.

7.3.2 Sample integrity is maintained during sampling and before chemical analysis.

7.3.3 If subsampling is performed, correct sampling procedures are followed to minimize sampling bias.

7.3.4 Sample preparation errors such as contamination and loss or alteration of constituents are prevented or minimized.

7.3.5 The samples, in the end, collectively reflect the target population within the context of the problem.

7.3.6 These attributes can be summarized into three broad categories:

7.3.6.1 A well-defined population,

7.3.6.2 Correct sampling procedures, and

7.3.6.3 Samples collected in the context of the stated problem.

[8] Gilbert, Richard O., *Statistical Methods for Environmental Pollution Monitoring*, Van Nostrand Reinholt Co., New York, NY 1987.

8. Practical Considerations

8.1 *Sampling Equipment*—The choice of appropriate sampling equipment can be crucial to the task of collecting a representative sample or a representative set of samples. Depending on the goals of the sampling activity, the sampling device used should minimize bias by having certain characteristics and capabilities, such as:

8.1.1 The ability to access and extract from every location in the target population,

8.1.2 The ability to collect a sample of proper shape,

8.1.3 The ability to collect a sufficient mass or volume of sample such that the distribution of particle sizes in the population are represented, and

8.1.4 The ability to collect a sample without the addition or loss of contaminants of interest.

8.2 *Equipment Design*— The improper design of sampling equipment may result in the collection of samples that are not representative of the population.

8.2.1 An example of equipment design influencing sampling results is samplers which exclude certain sized particles from a soil matrix or waste pile sample. The shape of some scoops may influence the distribution of particle sizes collected from a sample. Dredges used to collect river or estuarine sediments may also exclude certain sized particles, particularly the fines fraction which may contain a significant percentage of some contaminants such as polynuclear aromatic hydrocarbons (PAHs). Specific considerations in equipment design are outlined as follows.

8.2.1.1 *Sample Volume Capabilities*—Most sampling devices will provide adequate sample volume. However, the sampling equipment volumes should be compared to the volume necessary for all required analyses and the additional amount necessary for quality control (QC), split and repeat samples. Taking more than one aliquot to obtain an adequate sample volume can impact the representativeness of a sample.

8.2.1.2 *Compatibility*— It is important that sampling equipment, other equipment that may come in contact with samples (such as gloves, mixing pans, knives, spatulas, spoons, etc.) and sample containers be constructed of materials that are compatible with the matrices and analytes of interest. Incompatibility may result in the contamination of the sample and the degradation of the sampling equipment.

8.2.1.3 *Decontamination (see Practice D 5088) and Reuse*—Inadequate decontamination of sampling equipment can result in contamination of the sample and affects its representativeness. Due to design, some equipment is very difficult to adequately decontaminate. In some instances, it may even be desirable to either dispose of sampling equipment after use or to dedicate the equipment to a sampling point.

8.3 *Sampling Procedure*—Inappropriate use of sampling equipment is one of the largest sources of sampling bias. While it is beyond the scope of this guide to discuss it in depth, examples of how bias can be introduced during the sampling procedure are discussed in the following paragraphs. This guide does not provide comprehensive sampling procedures. It is the responsibility of the user to ensure that proper and adequate procedures are used.

8.3.1 *Ground Water*— For a more comprehensive discussion of sampling ground water refer to Guide D 4448.

8.3.1.1 Ground-water samples are usually collected through an in-place well, either temporarily or permanently installed. The following is a list of concerns that should be considered when collecting a ground-water sample.

(1) The well should be purged before collecting samples in order to clear the well of stagnant water which is not representative of aquifer conditions. Purging and sampling rates can cause chemical or physical changes in the water.

(2) Purging can be performed in such a way that the entire column of water is not removed. The best method for avoiding this situation is by lowering a pump or bailer into the top of the column of water.

(3) Bailing may stir up sediment in the well if conducted too vigorously. Increased turbidity can result in a higher metal content in the sample than in a non-turbid sample.

(4) Samples for volatile organic analysis should be collected in a fashion that minimizes agitation of the sample.

(5) Wells with in-place plumbing must also be purged. Samples should be collected immediately following purging. In order to collect a sample representative of ground water, samples should be collected before the water travels through any hoses or in-line treatment devices.

8.3.2 *Surface Water and Sediment*—For a more comprehensive discussion of sampling surface water and sediment, refer to Practice D 3370 and Guide D 4823. General and specific sampling concerns for collection of surface water and sediment samples are as follows:

8.3.2.1 *General Considerations*:

(1) Although bridges and piers may provide access for water and sediment sampling, these structures can also alter the nature of water flow and thus influence sediment deposition or scouring. Depending on the construction materials, these structures can contaminate samples collected in the immediate vicinity.

(2) Wading for water samples should be done with caution since bottom deposits are easily disturbed resulting in increased sediment in surface water samples and a removal of fines from the sediment sample.

8.3.2.2 *Rivers, Streams, and Creeks*:

(1) A good location to collect a vertically mixed surface water sample is immediately downstream of a riffle area. This location is also a likely area for deposition of sediment since the greatest deposition occurs where stream velocity slows down.

(2) Horizontal (cross-channel) mixing occurs in constrictions in the channel. However, this is a poor sediment sample collection area because of scouring.

(3) Surface water samples will be affected by point sources, such as tributaries and industrial and municipal effluents.

(4) Locations immediately upstream or downstream from the confluence of two streams or rivers may not immediately mix, and at times, due to possible back flow, can upset the normal flow patterns.

(5) Unless a stream is extremely turbulent, it is nearly impossible to measure the effect of a waste discharge or tributary immediately downstream of the source. Inflow frequently "hugs" the stream bank with very little cross-channel

mixing for some distance. Samples from quarter points across a stream may miss the wastes altogether and reflect only the quality of water upstream from the waste source. Samples collected within the portion of the cross section containing the wastes would indicate excessive effects of the wastes with respect to the river as a whole.

(6) When sampling tributaries, care should be exercised to avoid collecting water from the main stream that may flow into the mouth of the tributary on either the surface or bottom.

8.3.2.3 *Lakes, Ponds, and Impoundments*:

(1) Stratification of surface water is of greater concern in standing water. For example: A turbidity difference may occur vertically where a highly turbid river enters a lake, and each layer of the stratified water column may need to be considered. In addition, stratification may be caused by water temperature difference; cooler, heavier river water is beneath the warmer lake water.

(2) Dredges used to collect sediment samples can displace and miss lighter materials if allowed to drop freely.

(3) Core samplers used to sample vertical columns of sediment are useful when there is a need to know the history of sediment deposition. Coring devices also minimize the disturbance of fines at the sediment-water interface. However, coring devices can only sample a relatively small surface area. Depending on the core diameter, larger particles may be excluded and a single aliquot may not be sufficient for analytical needs.

8.3.3 *Soils*—For more detailed information, refer to Practice D 4547 and Guide D 4700. General areas of concern for sampling soils are as follows:

8.3.3.1 Soil samples for purgeable organic analyses should be collected with a minimum disturbance of the sample.

8.3.3.2 Samples for VOA analysis should not be mixed.

8.3.3.3 Two potential problems are associated with compositing soil samples. Low concentrations of contaminants present in individual aliquots may be diluted to the extent that the total composite concentration is below the minimum quantification limit. In addition, depending on the soil type, it can be very difficult to produce a homogeneous mixture.

8.3.4 *Waste*—Wastes referred to in this section include any liquid, solid, or sludge from pits, ponds, lagoons, waste piles, landfills, and open or closed containers such as drums, tank trucks, and storage tanks.

8.3.4.1 Any of these units may have multiple phases (floating solids, different density liquid phases, and sludge) and one or all of them may need to be sampled.

8.3.4.2 If sampling from access valves or ports on an open or closed container, care should be taken to be sure that the desired layer is sampled. For example, bottom sampling ports would allow only the heavier contents to be sampled while surface or top sampling would allow only sampling of the lighter layers.

8.4 *Subsampling (Field)*:

8.4.1 Different analyses require different types of bottles and preservation. For multiple analyses of the same waste stream, this may require subsampling in the field. Subsampling in the laboratory may require many of the same procedures; however, laboratory subsampling is beyond the scope of this guide.

8.4.1.1 Samples for organic analyses should always be taken from the first material collected. This minimizes loss of volatile organics during handling of the material.

8.4.1.2 If necessary, place the appropriate volume of material in a tray or other suitable container to composite. The volume is dependent on the needed analyses, and should be specified by the analytical laboratory.

8.4.1.3 Transfer the material into the required containers for analyses. If subsampling takes place, then the analytical sample is the final portion of the material subsampled from the original sampling unit and analyzed in the laboratory.

8.4.2 In subsampling, the original sampling unit can be considered as the population and the correct sampling procedures must be followed to ensure a representative subsample.

9. Keywords

9.1 bias; contaminated media; precision; representative; sample; waste; waste management

APPENDIX

(Nonmandatory Information)

X1. TWO CASE STUDIES OF REPRESENTATIVE SAMPLING

X1.1 Case Study One—Waste Pile Investigation

X1.1.1 *Background*— An industrial facility has managed recovery furnace slag and baghouse dust in a waste pile located on the site. No active management was occurring with the waste pile. No buried containers or extremely heterogenous material (debris) was suspected of being present in the waste pile based on facility records and interviews of personnel.

X1.1.1.1 Lead and cadmium were the constituents of concern based on process knowledge, and the possibility for the waste being hazardous by means of the Toxicity Characteristic (TC) Rule was the regulatory consideration. No preliminary information on the variability of lead and cadmium within the piles was available. The potential for off-site migration of contaminants by means of a drainage ditch that leads to a stream adjacent to the facility was an immediate concern.

X1.1.2 *Phase 1: Objective*—The primary objective of the initial investigation was to determine if the slag and baghouse dust in the waste piles were characteristic for lead via the Toxicity Characteristic Rule. A secondary objective was to provide preliminary information on potential migration and transport of contaminants from the waste piles off site.

X1.1.2.1 The sampling design for this initial investigation utilized a judgmental sampling strategy to provide a preliminary estimate of the lead and cadmium concentrations in the waste pile, the variability of contaminant concentrations in the pile, and the potential for leaching using the TCLP. Four areal composite samples were collected from the surface (0 to 6 in.) at the four quadrants of the waste pile. Borings were completed at the center of each area that was sampled on the surface. Each four-foot interval was analyzed to assess vertical variability.

X1.1.2.2 The following environmental samples were also collected using a judgmental approach:

(1) Several soil samples in the vicinity of the waste pile,

(2) Sediment upstream and downstream in a stream that borders the facility,

(3) Sediment in a ditch which contained run-off from the pile, and

(4) Two background soil samples.

X1.1.2.3 *Results*—Zinc, copper, cadmium, and lead were all elevated (compared to background) in the samples collected from the waste piles. Since lead and cadmium are TC Rule constituents, the TCLP was completed, and the lead results exceeded the regulatory level of 5 mg/L. Cadmium was just under the regulatory level of 1.0 mg/L. Lead and cadmium concentrations in the soil near the waste piles were 2 to 3 times above background, and the drainage ditch and downstream sediment sample also had elevated lead and cadmium levels.

X1.1.2.4 *Conclusion*— The waste piles contain slag and baghouse dust that is hazardous for lead. The waste pile requires further characterization to determine the variability in the pile. The presence of lead and cadmium in soils and the stream sediment downstream of the facility was confirmed and should be further investigated to determine the extent of contaminant transport.

X1.1.3 *Phase 2: Objective*—The sampling design utilized a systematic grid approach. This design will delineate horizontal and vertical variability in lead and cadmium concentrations. The Phase 1 investigation also provided a good estimate of the anticipated variability in the waste pile.

X1.1.3.1 The number of samples required to adequately characterize the waste pile was calculated based on the anticipated variability, the regulatory level of concern, and the specified confidence interval. The grid sizes were then adjusted to accommodate the projection on the required number of samples. Composite samples were collected within each grid cell based on one center point and eight points on the compass (45 deg intervals) equidistant from the center point.

X1.1.3.2 Twenty percent of the grids were designated for vertical characterization (at the grid center) at four-foot intervals, as well as surface (0 to 6 in.) sample collection. Additionally, ten percent of the grids were randomly designated for duplicate sampling (using a different aliquot pattern within the cell) to check the preliminary estimate on the variability.

X1.1.3.3 Additional environmental sampling was conducted that included a systematic sampling design for the stream adjacent to the facility with sediment samples collected at 100-ft intervals. A systematic approach was also used for the drainage ditch (50-ft intervals), with judgmental samples being collected at any location where visible staining was observed.

X1.1.3.4 *Results*—The results supported the initial investigation with lead consistently exceeding the TC Rule regulatory level; cadium was consistently below the regulatory level. Vertical differences in the lead and cadmium concentrations were not significant. Lead and cadmium were detected at elevated concentrations (relative to background) in the adjacent stream at a point downstream of the confluence with the drainage ditch.

X1.1.3.5 *Conclusion*— The waste pile was characteristic for lead and subject to Subtitle C of RCRA. There was no significant variability with depth, although several gradients were noticed across the grid (horizontally) based on lead concentration (scan) results.

X1.2 Case Study Two—Drum Sampling

X1.2.1 *Background*— An industry has two areas where drums of waste have been stored. One area is a warehouse adjacent to an off-line plating process that contains less than 25 drums (55 gal). The drums have manufacturers' labels indicating they contain an acid solution, and all of the drums are similar in appearance. A second area is a covered shed that has an estimated 100 drums from a variety of processes, several of which are no longer in use at the facility. Information on the content of these drums is not available.

X1.2.2 *Objective*—The objective of the initial investigation was to survey both of the storage areas for safety purposes, assess and record information on the drums, and open drums that were candidates for screening. All drums that were opened were surveyed using an organic vapor analyzer (PID, FID), pH paper, halogen detector, cyanide detector, and radiation meter.

X1.2.2.1 A judgmental sampling design was utilized in the warehouse where the anticipated variability was low. Based on the site screening (pH measurement), six samples were collected for pH analysis from the warehouse.

X1.2.2.2 The drums in the shed were screened in a similar fashion. A variety of results were obtained which included elevated pH, high organic vapor readings, and so forth. A simple random sampling design was used which called for the collection of 15 samples, with five from each major group of drums based on the screening (five corrosives, five potential ignitables with no halogens, and five with elevated halogen readings).

X1.2.2.3 *Results*—The warehouse samples were all corrosive with pH values from 1 to 2 S.U. The shed samples resulted in the collection of five corrosive wastes, three that were both ignitable and characteristic for non-halogenated TC Rule constituents, and two that were ignitable and characteristic for halogenated constituents. In summary, of the 15 drums sampled, 10 contained hazardous waste.

X1.2.2.4 *Conclusions*— All of the drums in the warehouse are subject to Subtitle C of RCRA. The drums in the shed require further assessment due to the fact that several of those sampled did not contain hazardous waste.