Coal Combustion Residual Legacy Rule Initial 6-Month Applicability Extension Report

Closed William J. Neal Station, Velva, ND

Prepared for:
Basin Electric Power Cooperative
1717 East Interstate Avenue
Bismarck, ND 58503

Prepared by
Barr Engineering Co.

November 2024

234 West Century Avenue
Bismarck, ND 58503
701.255.5460

BARR

Certification

I hereby certify that I have examined the facility and, being familiar with the provisions of 40 CFR 257 Subpart D, attest that this Field Investigation Work Plan and Certification have been prepared in accordance with good engineering practice, including consideration of relevant industry standards and the requirements of 40 CFR § 257.100(f)(1)(iii). I further certify that I am a duly Licensed Professional Engineer under the laws of the State of North Dakota and that I have professional experience with surface impoundment design, operation, monitoring and closure.

The services performed by Barr for this Project have been conducted in a manner consistent with the level of skill and care ordinarily exercised by other members of the profession currently practicing in this area. No other warranty, expressed or implied, is made.

REGISTERED PROFESSIONAL ENGINEER
KEVIN L. SOLIE
PE-9488
DATE 11-6-2024
NORTH DAKOTA

Kevin L. Solie
North Dakota PE-9488

November 6, 2024
Date

CCR Legacy Rule Initial 6-Month Applicability Extension Report

November 2024

Contents

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Figures

Appendices

1 Introduction

On May 8, 2024, EPA finalized the Coal Combustion Residual (CCR) Legacy Rule, which includes new regulations for inactive surface impoundments at inactive electric utilities, referred to as "legacy CCR surface impoundments." In addition, the new regulation included requirements for CCR surface impoundments and landfills that closed prior to the effective date of the 2015 CCR Rule and other areas where CCRs were disposed of or managed on land outside of regulated units at active facilities. These newly regulated areas are referred to as “CCR management units” or CCRMUs. On behalf of Basin Electric Power Cooperative (Basin Electric), Barr Engineering Co. (Barr) has prepared this initial CCR Legacy Rule 6-month applicability extension report for the William J. Neal ash pond disposal site.

1.1 Background information

Basin Electric owns and previously operated the William J. Neal Station (WJN), a coal-fired electrical generation station located near Velva, ND. WJN ceased operations in the late 1980s and was subsequently decommissioned and demolished in the late 1990s. CCRs (fly ash and sludge) from WJN were deposited in a disposal area (surface impoundment) located west of the plant site. The site had been previously reviewed by the EPA and received a No Further Remedial Action Planned (NFRAP) designation.

Based on the date WJN ceased providing power to electric power transmission systems, it is considered an “inactive facility” under the CCR Legacy Rule and potentially falls under Legacy Rule regulation. Owners of Legacy surface impoundments must make an applicability determination and prepare an applicability report, indicating whether or not the unit is subject to the Rule. Existing and available information, however, does not provide a sufficient basis to determine applicability, i.e., it is not evident that the unit contained free liquids on or after October 19, 2015.

1.2 Purpose

The Legacy Rule offers owners the ability to secure additional time to complete an applicability report for the sole reason of determining through field investigation whether the unit contains both CCRs and liquids (and is subject to all the CCR Legacy Rule requirements for inactive impoundments). Basin Electric intends to use the recent EPA memorandum entitled “Considerations for the Identification and Elimination of Free Liquids in Coal Combustion Residuals (CCR) Surface Impoundments and Landfills” dated April 22, 2024, to guide field investigation efforts. The EPA memorandum is attached as Appendix A.

If, during implementation of the written field investigation workplan (described in detail in later sections), Basin Electric determines that the unit contains free liquids, Basin Electric will cease operating under the extension provisions and prepare an applicability report within 14 days of determining that the unit contains free liquids. Basin Electric would also comply with the remaining Legacy Rule requirement deadlines under new timeframes, to be determined by adding the total length of the extension(s) to each of the deadlines specified in the Legacy Rule.

Alternatively, if Basin Electric determines that the closed WJN surface impoundment does not contain both CCR and liquids during implementation of the written field investigation work plan, Basin Electric would prepare a notification stating that the field investigation has concluded and has determined that the unit does not contain both CCR and liquids (and therefore does not meet the definition of a Legacy CCR surface impoundment. Basin Electric would place the notification in the facility's operating record as required by § 257.105(k)(3).

1.3 Extension Report Requirements

The Legacy Rule applicability extension report (extension report) consists of three parts. First, the extension report must include general identifying information about the potential legacy impoundment, including the name associated with the unit, and information about the location of the unit at the facility. This information is same as the first three elements of the applicability report under § 257.100(f)(1)(i)(A) through (C). Second, the extension report must include a statement by the owner or operator that available information does not provide a sufficient basis to determine that the inactive impoundment contained free liquids on or after October 19, 2015. Finally, the applicability extension report must contain a written field investigation work plan. The purpose of this plan is to describe the approach the owner or operator intends to follow to determine whether the inactive impoundment contains free liquids.

2 General Information Requirements

Following a restatement of the regulatory text, each requirement is addressed in *italics*.

2.1 Owner Contact information

§ 257.100(f)(1)(i)(A). The name and address of the person(s) owning and operating the legacy CCR surface impoundment with their business phone number and email address.

The WJN disposal site is owned by Basin Electric Power Cooperative, 1717 East Intestate Avenue, Bismarck, ND. Basin Electric Power Cooperative's business phone number is 701.223.0441. Basin Electric Power Cooperative's corporate email address is webeditorbepc@bepc.com.

2.2 CCR Surface Impoundment Name

§ 257.100(f)(1)(i)(B). The name associated with the legacy CCR surface impoundment.

The name commonly associated with the legacy CCR surface impoundment is William J. Neal ash pond disposal site.

2.3 Location

§ 257.100(f)(1)(i)(C). Information to identify the legacy CCR surface impoundment, including a figure of the facility and where the unit is located at the facility, facility address, and the latitude and longitude of the facility.

The facility is located south and west of the intersection of US Highway 52 and 14th Ave N in Velva, ND, Latitude 48.026647 N, Longitude 100.885697 W. Figure 1 shows the general location of the facility.

3 Owner/Operator Statement Requirements

Following a restatement of the regulatory text, each requirement is addressed in *italics*.

§ 257.100(f). A statement by the owner or operator that to the best of their knowledge or belief, existing and available information does not provide a sufficient basis to determine that the unit contained free liquids on or after October 19, 2015.

3.1 Statement

I, Troy Tweeten, have personally examined and am familiar with the information submitted in this applicability extension report and all attached documents, and that, based on my inquiry of those individuals immediately responsible for obtaining the information, I believe that the submitted information is true, accurate, and complete. To the best of Basin Electric Power Cooperative's knowledge or belief, as current owner of the William J. Neal Station ash pond disposal site, existing and available information does not provide a sufficient basis to determine that the unit contained free liquids on or after October 19, 2015.

Troy Tweeten

Troy L. Tweeten
Senior vice president of Generation

November 6, 2024
Date

4 Field Investigation Workplan

The required elements of the WJN field investigation work plan are discussed below. Following a restatement of the regulatory text, each requirement is addressed in *italics.*

4.1 Site Characterization Approach

§ 257.100 (f)(1)(iii)(3)(i). A detailed description of the approach to characterize the physical, topographic, geologic, hydrogeologic, and hydraulic properties of the CCR in the unit and native geologic materials beneath and surrounding the unit, and how those properties will be used to investigate for the presence of free liquids in the CCR unit.

In general, Basin Electric will use the existing site-specific information including historic aerial photographs, maps, soil boring logs, soil boring samples, monitoring well installation data, and other geologic and hydrogeologic site information to inform the preparation of a Conceptual Site Model (CSM) for the WJN ash disposal site. Preparation of the CSM will also require additional field efforts. Basin Electric intends to utilize direct measurements and observations which enable the identification or measurement of free liquids in CCRs. In a groundwater context, standard piezometers and monitoring wells are common tools used for the direct measurement of water levels in the saturated zone. The presence of free-standing water in a well or piezometer is a direct indicator of free liquids which have drained from pore spaces into the boring under ambient pressures and temperatures.

In 2024, Basin Electric installed six piezometers around the perimeter of the site to determine the elevation of the local water table. Two borings advanced through perimeter berms were also completed. To date, a series of three water level measurements have been completed in the newly installed piezometers. While current groundwater elevation data appears to indicate the piezometric surface is below the elevation of CCRs in the closed surface impoundment, Basin Electric plans to install additional piezometers into and through the CCRs in the impoundment to determine the presence or absence of free liquids. The additional piezometers, along with piezometers installed in 2024 and historic soil boring and monitoring well installation records will be integrated into a new CSM. No other CCR Unit instrumentation or monitoring devices are present at the site.

4.2 Methods and Tools

§ 257.100 (f)(1)(iii)(3)(ii). A detailed description of the methods and tools that will be employed to determine whether the inactive impoundment contains free liquids, the rationale for choosing these methods and tools, and how these methods and tools will be implemented, and at what level of spatial resolution at the CCR unit to identify and monitor the presence of free liquids.

EPA guidance specific to the Legacy Rule (Memorandum to Docket ID No. EPA-HQ-OLEM-2020-0107 - Considerations for the identification and Elimination of Free Liquids in Coal Combustion Residuals (CCR) Surface Impoundments and Landfills (40 CFR Part 257, Subpart D)) recommends the use of piezometers or monitoring wells to determine the presence of free liquids. Accordingly, Basin Electric's field investigation will include the extensive use of piezometers.

Future site work would include the drilling and installation of twenty-four interior piezometers (through CCR material) at a rate of approximately one piezometer per half-acre. The driller is anticipated to employ a 7822DT GeoProbe™ to collect continuous sample core in 5' intervals utilizing direct-push technology. A geologist/engineer will log the soil and observe the drilling and determine piezometer screen depth. Samples of solids (CCRs and native soils) will be collected at 2.5' intervals and retained for future laboratory analysis, if deemed necessary. Wells would be 1" diameter PVC with 5' or 10' well screens. Sand will be placed around and above the well screen (as applicable) and bentonite seal will be placed above the sandpack to ground surface.

If there are any free liquids in the pore spaces around the piezometer screen, it will drain into the piezometer and the water level in the standpipe will rise to a level related to the level of saturation in the pore spaces. In essence, the water level in the piezometer is a direct measure of the readily separable liquids in the vicinity of the piezometer and will provide direct evidence of the presence of free liquids.

4.3 Groundwater elevation determination

§ 257.100 (f)(1)(iii)(3)(iii). A detailed description of how groundwater elevations will be determined, and at what level of spatial resolution, in relation to the sides and bottom of the CCR unit and how any interaction of the groundwater table with the CCR unit will be evaluated, and at what level of spatial resolution.

After the top of casing (TOC) for each well has been surveyed to 0.1 foot accuracy, groundwater elevations will be determined manually, using an electric water level tape by field personnel. The site has a small footprint and the anticipated number of measuring points (six perimeter piezometers and 24 piezometers within the limits of in-place CCRs) is relatively low. Accordingly, the water level measurements would be taken in a relatively narrow time window and would provide a point-in-time snapshot of water levels at WJN. Basin Electric may elect to automate the process using pressure transducers and telemetry but given the size of the site and proximity to Basin Electric staff, automation may be unnecessary.

If CCR appear to be dry during drilling, piezometers would be screened utilizing a 10' screen extending five feet below to five feet above the CCR/native soil interface, i.e., the base of the surface impoundment. If CCRs appear to contain free liquids during drilling, a five-foot screen would be place at the CCR/native soil interface, extending upwards into the CCRs.

4.4 Stormwater evaluation

§ 257.100 (f)(1)(iii)(3)(iv). A plan for evaluating stormwater flow over the surface of the unit, stormwater drainage from the unit, and stormwater infiltration into the unit and how those processes may result in the formation of free liquids in the CCR unit. This plan must include a current topographic map showing surface water flow and any pertinent natural or man- made features present relevant to stormwater drainage, infiltration and related processes.

Stormwater flow and direction will be determined utilizing a one-foot contour interval contour map of the site and surrounding area. During closure, Basin Electric consolidated waste into an approximately 16-acre area located in the eastern portion of the former pond location. Basin Electric installed an engineered cover system including an 18-inch-thick compacted clay layer overlain by an additional 18 inches of cover soil. Climatic conditions (relatively low local precipitation, coupled with high *evapotranspiration rates) tend to diminish the likelihood of stormwater infiltration. Further, the robust design and thickness of the cover system and site grading to promote positive drainage both function to greatly reduce the infiltration of stormwater.*

Utilizing EPA's HELP Model, the site-specific conditions discussed above will be input to estimate infiltration at the site. The one-foot contour map will be reviewed to identify areas that could be interpreted to collect or accumulate stormwater. Finally, contour map will undergo ground-truthing via visual inspection, focusing on evidence of erosion or stormwater ponding.

4.5 Estimated Timeline

§ 257.100 (f)(1)(iii)(3)(v). An estimated timeline to complete the workplan and make a determination if the CCR unit contains free liquids.

Basin Electric anticipates the implementation of the field work plan will begin during early to mid-2025 and will continue through the year to capture an overview if there is seasonal variation. The exact timing of the site drilling and piezometer installation is currently unknown and is dependent on contractor availability as well as weather and soil conditions. After piezometer installation, water levels will be obtained on a monthly basis for at least six months, in order to observe any seasonal fluctuations in the potentiometric surface. As this is expected to take additional time, this is the first of two potential extension requests that may need to be prepared and posted to Basin Electric's publicly available CCR compliance data website.

4.6 Interpretation of Results

§ 257.100 (f)(1)(iii)(3)(vi). A narrative discussion of how the results from implementing the workplan will determine whether the unit contains free liquids specified.

If there is any free liquid in the pore spaces in CCRs around the piezometer screen, it will drain into the piezometer and the water level in the standpipe will rise to a level related to the level of saturation in the pore spaces. In essence, the water level in the piezometer is a direct measure of the readily separable liquids in the vicinity of the piezometer and will provide direct evidence of the presence of free liquids.

4.7 Anticipated Problems

§ 257.100 (f)(1)(iii)(3)(vii). A narrative discussion describing any anticipated problems that may be encountered during implementation of the workplan and what actions will be taken to resolve the problems, and anticipated timeframes necessary for such a contingency.

The direct-push drilling method may not be able to penetrate well-indurated layers of CCRs, if present at the site. The initial response will be to offset and attempt to penetrate at 5-10' away from initial boring. The drilling method would then be modified, using GeoProbe™ auger attachments. Should these methods be determined to be unworkable, a larger hollow-stem auger (HSA) rig would be utilized to complete the borings. It is anticipated that a HSA rig could be mobilized to the site within 30 days of determining the need. A test pit or open excavation may be utilized in certain areas if appropriate.

4.8 Engineer Certification

§ 257.100 (f)(1)(iii)(3)(viii). The owner of the CCR unit must obtain a written certification from a qualified professional engineer stating that the field investigation work plan meets the requirements of paragraph (f)(1)(iii)(A)(3) of this section.

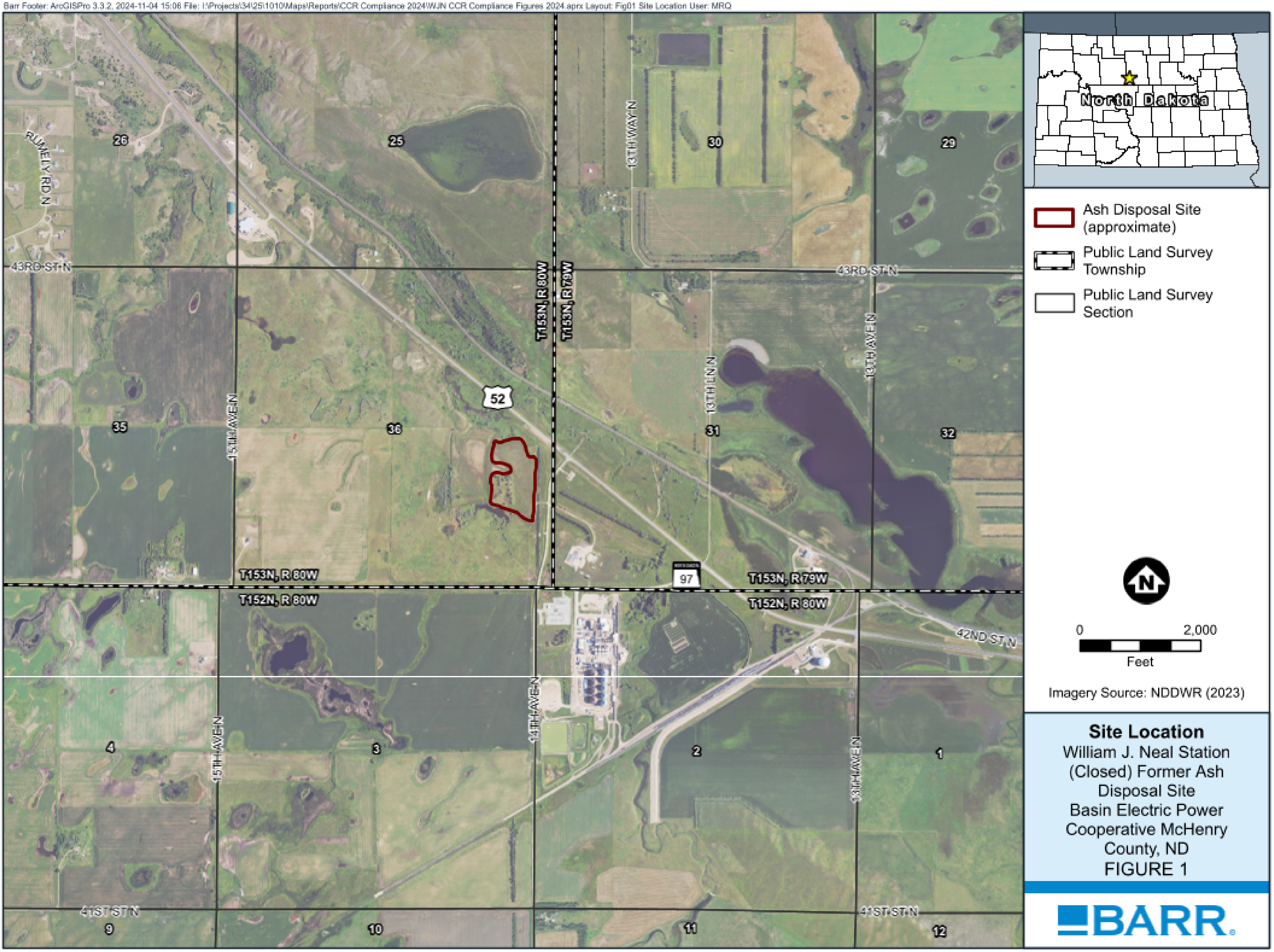
Please see qualified professional engineer certification at beginning of this report.

Figures

Figure 1

Site Location Map

Barr Footer: ArcGISPro 3.3.2, 2024-11-04 15:06 File: I:\Projects\34\25\1010\Maps\Reports\CCR Compliance 2024\WJN CCR Compliance Figures 2024.aprx Layout: Fig01 Site Location User: MRQ



Site Location
William J. Neal Station (Closed) Former Ash Disposal Site
Basin Electric Power Cooperative McHenry County, ND
FIGURE 1

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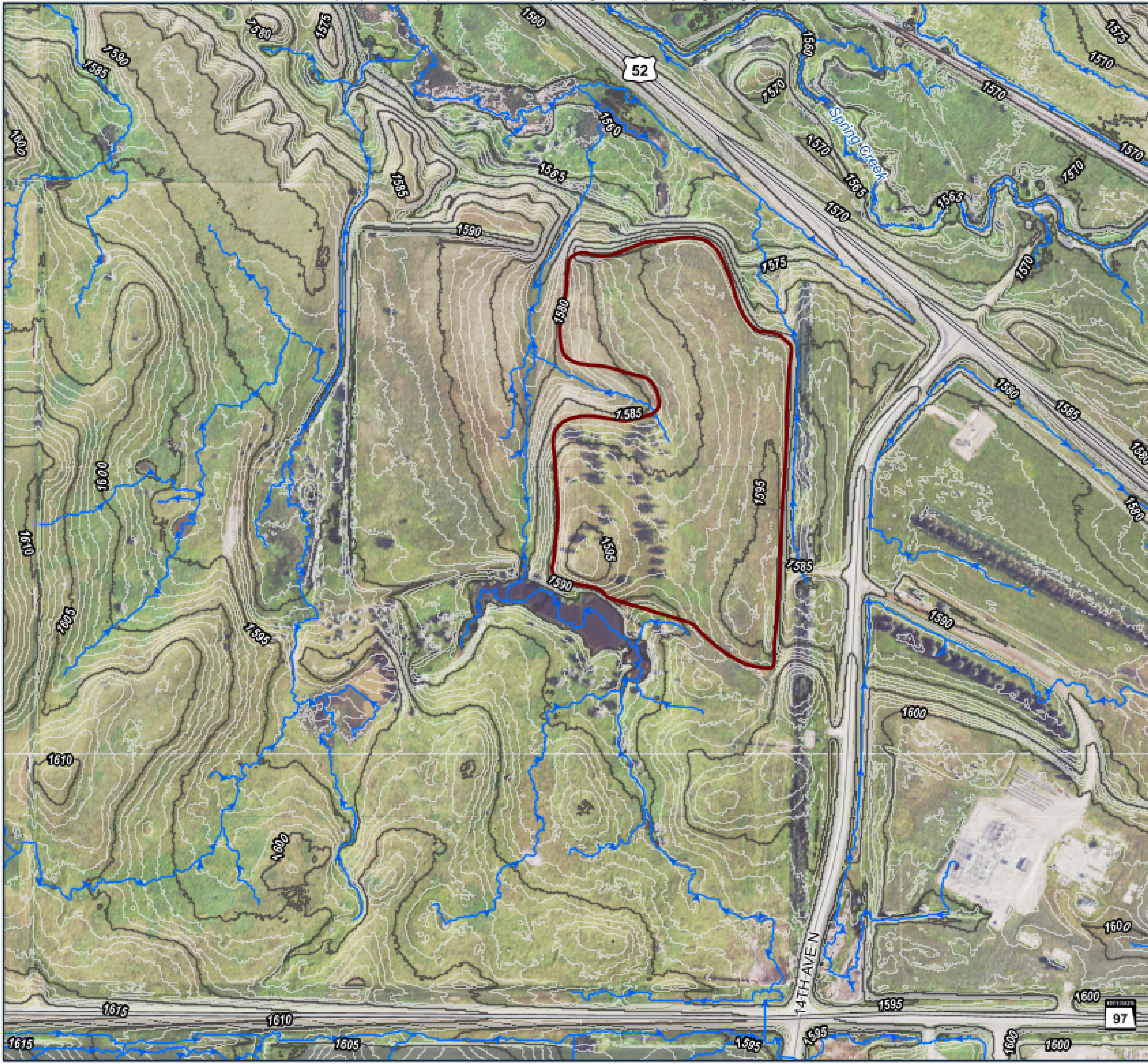
Figure 2

Stormwater Flow Map



Ash Disposal Site (approximate)
Major Highway
5-foot Contour
1-foot Contour
Inferred Water Flow Direction

Notes:
Elevation data derived from 2017 LiDAR data, downloaded from the ND Dept. of Water Resources LiDAR Dissemination MapService.

N

0 500
Feet

Imagery Source: NDDWR (2023)

Surface Water Flow
William J. Neal Station (Closed) Former Ash Pond Disposal Site
Basin Electric Power Cooperative
McHenry County, ND
FIGURE 2

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Appendix A

EPA Memorandum

Appendix A EPA Memorandum

MEMORANDUM

DATE: April 22, 2024

SUBJECT: Considerations for the Identification and Elimination of Free Liquids in Coal Combustion Residuals (CCR) Surface Impoundments and Landfills (40 CFR Part 257, Subpart D)

FROM: William C. Brandon
Office of Land and Emergency Management,
Office of Resource Conservation and Recovery (5304-T)

TO: Docket ID No. EPA-HQ-OLEM-2020-0107

Executive Summary

The term "free liquids" is defined in the regulations to mean "liquids that readily separate from the solid portion of a waste under ambient temperature and pressure." 40 CFR 257.53. Free liquids include freestanding liquids and all readily separable porewater within the CCR unit, whether the porewater was derived from sluiced water, surface water, groundwater that intersects the CCR within the impoundment, or other sources.

Under the regulations a facility owner or operator will need to determine whether free liquids are present within the unit. For example, the presence of free liquids is relevant to determining whether a unit is an inactive or legacy impoundment. See 40 CFR 257.53. The closure with waste in place performance standard in 40 CFR 257.102(d)(2)(i) requires the owner or operator to eliminate all free liquids. A unit that is consistently or routinely inundated with groundwater due to seasonal or other variations, excluding force majeure events (e.g., hurricane) would not meet this standard.

Many of the tools and methods needed to identify and eliminate free liquids are already widely used by industry to investigate and close surface impoundments. For example, tools that may be used to identify free liquids include soil borings and cone penetrometers to map the stratigraphy of the CCR unit and characterize the geotechnical and hydraulic properties of the various CCR layers, as well as the installation of traditional piezometers, monitoring wells and vibrating wire piezometers to monitor pore pressures and water levels. While a variety of tools and methods can be used to monitor groundwater, EPA recommends the use of networks of properly constructed wells and piezometers, screened in the appropriate locations and depths, to determine if free liquids are present, as such devices directly measure water levels under ambient conditions at specific locations.

Similarly, tools and methods to eliminate free liquids within the CCR, such as rim ditches, sumps, underdrain systems, pumping wells, manifolded extraction wellpoints, etc., are also currently widely employed by industry. These elimination technologies also provide diagnostic and confirmatory insights into the presence and nature of free liquids at a given CCR unit, e.g., rim ditches and open excavations enable direct observation of free liquids. EPA recommends that facilities rely on a holistic evaluation of all information collected from site-wide monitoring networks (e.g., piezometers, vibrating wire

piezometers, monitoring wells, etc.), as well as data collected from actual dewatering efforts for the elimination of free liquids. Where used, a monitoring network design should account for the size and complexity of the unit with a sufficient density of monitoring points to determine that free liquids have been eliminated in all areas of the unit.

This memorandum provides general guidance on site-specific strategies and approaches to identify, measure, monitor and eliminate free liquids. Successful elimination of free liquids relies on a well resolved understanding of the character and variability of the site-specific geology and hydrology, as well as the CCR themselves. Such information is usually compiled into a Site Conceptual Model (CSM). Some recommendations for the elements needed to construct a CSM if one does not already exist, or to augment a weak or poorly resolved CSM, are also provided below.

In summary, EPA regulations require meeting the performance standards for closure and post closure over the long term and this will necessarily involve careful consideration of all potential sources of free liquids. Facility owners and operators with CCR units undergoing closure with waste in place that contain free liquids must determine the necessary measures to ensure that all free liquids are eliminated prior to installing the final cover system as required by 40 CFR 257.102(d)(2)(i). Data are typically needed to demonstrate that saturated CCR does not remain in the base of the unit prior to the installation of the final cover system, especially if the unit is consistently or routinely inundated with groundwater.

This document provides guidance to EPA Regional and State permitting authorities as well as to owners and operators of CCR units and the general public on how EPA intends to exercise its discretion in implementing the statutory and regulatory provisions that concern determinations of whether free liquids are present in CCR units. See, 40 CFR 257.53, 257.102(d)(2)(i).

The statutory provisions and EPA regulations described in this document contain legally binding requirements. This document does not substitute for those provisions or regulations, nor is it a regulation itself. Thus, it does not impose legally binding requirements on EPA, States, or the regulated community, and may not apply to a particular situation based upon the circumstances. EPA and State decisionmakers retain the discretion to adopt approaches on a case-by-case basis that differ from this guidance where appropriate. Any decisions regarding a particular facility will be made based on the statute and regulations. Therefore, interested parties are free to raise questions and objections about the substance of this guidance and the appropriateness of the application of this guidance to a particular situation.

The statements in this document are intended solely as guidance. This document is not intended, nor can it be relied upon, to create any rights enforceable by any party in litigation with the United States. EPA may decide to follow the guidance provided in this document, or to act at variance with the guidance based on its analysis of the specific facts presented.

1. Introduction

"Free liquids" are currently defined in 40 CFR 257.53 as "liquids that readily separate from the solid portion of a waste under ambient temperature and pressure." The regulations also specify that a CCR unit "contains both CCR and liquids" when "CCR and liquids are present in a CCR surface impoundment except where the owner or operator demonstrates that the standard in 40 CFR 257.102(d)(2)(i) has been met." All CCR units closing with waste in place are required to eliminate free liquids, a requirement adopted in the 2015 CCR Rule to prevent or mitigate groundwater contamination, enhance structural stability and other factors.

The definition of "free liquids" and other related definitions are provided below, as well as the performance standard for the elimination of free liquids. A range of specific methods for *identifying* and *measuring* free liquids within CCR units and other considerations also follow, below. Common methods and approaches for *elimination* of free liquids, including those in widespread use as common industry practice, are also listed and described further below. Confirmation methods, approaches, and metrics for demonstrating *elimination* of free liquids pertinent to the scale of applicable CCR units are also presented below.

2. Definition, Identification and Characterization of Free Liquids

2.1. Performance Standard for Removal of Free Liquids – Regulatory Citations

The existing regulations require the elimination of free liquids, which is a permanent, sustainable, non-changing condition, as follows:

> 40 CFR 257.102(d)(1)(i) and (ii):
>
> (d) *Closure performance standard when leaving CCR in place —*
>
> (1) The owner or operator of a CCR unit must ensure that, at a minimum, the CCR unit is closed in a manner that will:
>
> (i) Control, minimize or eliminate, to the maximum extent feasible, post-closure infiltration of liquids into the waste and releases of CCR, leachate, or contaminated run-off to the ground or surface waters or to the atmosphere;
>
> (ii) Preclude the probability of future impoundment of water, sediment, or slurry;
>
> 40 CFR 257.102(d)(2)(i) and (ii):
>
> (2) *Drainage and stabilization of CCR units.* The owner or operator of any CCR unit must meet the requirements of paragraphs (d)(2)(i) and (ii) of this section prior to installing the final cover system required under paragraph (d)(3) of this section.
>
> (i) Free liquids must be eliminated by removing liquid wastes or solidifying the remaining wastes and waste residues.
>
> (ii) Remaining wastes must be stabilized sufficient to support the final cover system.

2.2. Definitions and General Performance Standard for Removal of Free Liquids

The final rule titled "Hazardous and Solid Waste Management System: Disposal of Coal Combustion Residuals from Electric Utilities; Legacy CCR Surface Impoundments" incorporated a definition of "liquids" into the regulations: "any fluid (such as water) that has no independent shape but has a definite volume and does not expand indefinitely and that is only slightly compressible. This encompasses all of the various types of liquids that may be present in a CCR unit, including water that was sluiced into an impoundment along with CCR, precipitation, surface water, and groundwater that has migrated into the impoundment due to the construction of the unit, which may be found as free water or standing water ponded above CCR or porewater intermingled with CCR." See 40 CFR 257.53. The main types of liquids commonly found in CCR units include:

- Water introduced into the unit from precipitation and/or surface water run-on.
- Water directly introduced to the unit from sluicing or other plant operations.
- Water or groundwater that directly or indirectly enters or intrudes into the unit's subsurface, either laterally and/or vertically, i.e., from underneath or above, or the sides.
- Interstitial water found in the pore spaces of the ash, i.e., pore water.
- Ponded water (sometimes referred to as "free water" or "surface water"), e.g., within an impoundment, occurring above the top surface of the solid or semi-consolidated CCR.
- Or any water or other liquids from any source which occur or come to be located in the unit, particularly as pore water within the CCR matrix.

"Free liquids" represent a subset of the entire universe of "liquids" potentially present at a given CCR unit. To fully appreciate the term "free liquids," it must first be acknowledged that "pore water" within the ash matrix, i.e., interstitial spaces between the "skeleton" of solid particles comprising the CCR, can also contain all the types of liquids discussed above.

The existing regulation defines "free liquids" as those liquids that *readily separate* from the CCR *under ambient temperature and pressure.* Removal of *free liquids* therefore refers to the removal, by a variety of means discussed below, of the ponded water and *readily separable* interstitial water within the CCR.

2.3. Performance Standard for Removal of Free Liquids – Temporal Considerations

A key objective of this memorandum is to present methods and tools currently available to meet the performance standards included in 40 CFR 257.102(d). As stated above, pursuant to 40 CFR 257.102(d)(2), CCR units closing with waste in place must eliminate free liquids from the unit *prior to* installation of the final cover system. The use of the word "eliminate" requires the owner or operator to ensure that free liquids will not return. In this respect, the term "*eliminate*" in the regulation takes its ordinary meaning. For example, Merriam-Webster defines eliminate to mean "to put an end to or get rid of." In accordance with this plain language, the regulation requires a permanent sustained condition where free liquids are no longer present in the unit and remain so before and after the installation of a cover system or other engineered systems rather than a temporary effort designed only to facilitate construction activities or other short-term actions. The regulation further specifies how this standard is to be met, i.e., by "removing liquid wastes or solidifying the remaining wastes and waste residues." 40 CFR 257.102(d)(2)(i).

The requirement to eliminate free liquids obligates the facility to take engineering or other measures as necessary to ensure that all free liquids, from whatever source, have been permanently removed ("eliminated") from the unit prior to installing the final cover system, and that the unit will remain in this condition into the foreseeable future under reasonably expected seasonal, climatic, or other variations. Consequently, where the waste in the unit is continually inundated with liquids, water balance controls of some type are normally necessary to prevent re-wetting of CCR left in place. These controls function to prevent the generation and migration of leachate as a point- or nonpoint source into ground water and/or adjacent surface water. Such controls can include groundwater exclusion measures designed to minimize the infiltration of water to the wastes, e.g., subsurface barriers such as basal liners and lateral barriers (e.g., slurry walls), focused groundwater extraction systems, and combinations thereof.

Removal of CCR in contact with groundwater is another approach that can meet the performance standards at 40 CFR 257.102. This can include either removal of all CCR from the unit, or a hybrid approach, in which only the CCR below the water table is removed. For example, where only a portion of the unit is below the water table, some facilities have consolidated the CCR into a smaller footprint above the water table; another approach that some facilities have used is to temporarily remove CCR from below the water table and build up the base of the unit so that there is no longer any contact between groundwater and the CCR in the unit.

2.4. Methods and approaches for Identification of Free Liquids at CCR units

This section discusses tools, methods, and approaches currently available for identification of free liquids in CCR. While not intended to be a comprehensive or prescriptive list, commonly used and readily available methods as well as some alternative methods are identified below. Site-specific factors such as topography, geology, hydrology, characteristics of the CCR, and other factors are used by facilities to develop a plan for identifying and removing free liquids. Such site-specific approaches, however, should also consider temporal and spatial variability particular to each situation, pertinent to identification and delineation of free liquids. Since units closing with waste in place will need to identify and eliminate free liquids, a central objective is to characterize the nature and extent of the free liquids to enable focused elimination efforts by appropriate engineering approaches. The compilation of site information necessary to guide free liquids elimination or other engineering actions is commonly referred to as the Conceptual Site Model (CSM), which is discussed in detail below.

2.5. Conceptual Site Models

An effective assessment of free liquids at the site scale would normally be informed by a robust CSM which addresses the CCR and areas surrounding the unit at the appropriate level of detail. General guidance regarding CSMs (also referred to in the literature as Site Conceptual Models, i.e., SCMs) can be found in many forms and formats, including *Environmental Cleanup Best Management Practices: Effective Use of the Project Life Cycle Conceptual Site Model*. The latter is a quick reference fact sheet which includes references to other useful publications pertinent to CSM development and use. The CSM is an iterative, 'living representation' of a site that summarizes and helps project teams visualize and understand available information.

A CSM reflects the current characteristics of the site as well as the potential actions or activities planned for the site. In this respect, a CSM developed for free liquids elimination at a CCR site would have a different focus than a CSM constructed to guide remediation of dissolved chemicals in groundwater, although they might contain some common elements. Focused CSMs for the elimination of free liquids need to iteratively guide and represent CCR characterization efforts including the nature and distribution of pore waters contained within the CCR and the surrounding geologic materials. Both free liquids above and below the water table need to be understood in sufficient detail to enable planning and implementation of dewatering efforts and other approaches designed to eliminate free liquids. The focused CSM should target physical geology, hydrogeology, and hydrology, but can sometimes also consider chemistry and geochemistry of the liquids to be eliminated with respect to disposal options (e.g., NPDES permits), treatment train options, and potential maintenance operations for dewatering systems, etc. Site stability and other geotechnical considerations are critical elements to safe operations and overall site closure strategies. While geotechnical data collection efforts needed for these purposes often contribute significantly to the CSM for purposes of elimination of free liquids, the following sections intentionally do not consider the full scope of necessary geotechnical considerations. Any references to geotechnical data of various categories, below, are intended only to inform and illustrate the identification and elimination of free liquids. Geotechnical considerations warrant deliberate focused strategies which can go beyond that needed only for identifying and eliminating free liquids. EPA expects that all necessary site-specific geotechnical data will be collected under the direction of a licensed PE to ensure safe working conditions and slope stability are maintained throughout the closure process.

In the following paragraphs, EPA outlines some of the key elements for such a CSM. CSMs are by nature living documents, which are intended to be updated regularly as new information or technology becomes available. In situations where groundwater has the potential to intersect with any CCR remaining in the unit, characteristics of the groundwater system both inside, outside and beneath the unit need to be determined to assess the potential for groundwater interactions in the future, particularly intrusion of groundwater into CCR. Similarly, potential interactions between groundwater and surface water and interactions of surface water with porewater may be important at units in riverine or other hydraulically dynamic settings. Understanding if there is any potential for porewater/groundwater/surface water interaction is a critical element to consider when assessing the long-term viability of a CCR unit closure design.

2.6. Physical, Hydraulic, Geotechnical and Chemical Properties of the CCR

As a first step, EPA recommends that CSMs for elimination of free liquids include characterization of physical and hydraulic and chemical properties of the various layers or other CCR deposits in the unit. EPA recommends that, at a minimum, the CSM include the elements listed below, and that these elements be addressed at an appropriate level of detail to match the size and complexity of the unit and its immediate surroundings.

- Geotechnical and hydraulic data such as grain size, permeability and other relevant parameters.
- Variability and heterogeneity at unit scale.
- Spatial distribution of permeability.
- Presence and spatial position of impermeable layers or zones in CCR or geologic materials surrounding the CCR unit.
- Presence and spatial position of highly permeable layers or zones in CCR or geologic materials surrounding the CCR unit.
- Identification and location of preferential pathways related to geologic materials or engineered structures in CCR or surrounding the CCR unit.
- Water levels and porewater pressure distribution in CCR above, within, and below the water table.

A key objective for the CSM is a well resolved representation of the liquids distribution within the CCR, including regions above and below the water table, in order to identify areas where free liquids need to be eliminated. The spatial variability of the liquids distribution, and its relationship to the ambient water levels, i.e., hydraulic head from groundwater, are needed to inform and construct a suitable water level measurement network to evaluate distribution and sustained elimination of free liquids over time. Relevant considerations include the following:

- Locations, depths, screened intervals, or measurement intervals of piezometers, monitoring wells, vibrating wire piezometers, pressure transducers or other devices.
- A sufficient number of monitoring points installed at appropriate locations and depths dependent on complexity of the CCR unit and CCR .
- At units where groundwater may intersect CCR, vibrating wire piezometers or additional water level measuring devices are needed, especially in the deepest parts of CCR unit.
- Surface water features, including impounded water, rivers, streams, wetlands', etc., at locations above and adjacent to CCR units, and their impact on water levels and hydraulic head pressure within the CCR, e.g., staff gauges, stilling wells, automatic water level recording devices.
- Presence and magnitude of any groundwater mounding.
- Pore pressure/hydraulic head distribution should be evaluated in conjunction with the presence and spatial position of perched layers, preferential pathways, etc.
- Seasonal or temporal variations or water levels and pore pressures should be assessed with time-series measurements. Use of pressure transducers or other recording measurement devices should be strongly considered.
- Collection of time-series data for precipitation infiltration and barometric pressure should also be strongly considered.

Characterizing the chemistry of the CCR and liquids contained within the CCR in the unit is also an important element to a CSM. Such information can be critical for a CSM tasked with guiding dewatering effort, for a number of reasons, as itemized below.

- Potential for the chemistry of CCR and liquids in the unit to induce physical, chemical, or biological processes which can create problematic buildup of ash, chemical precipitates or bacteria around the well screens, pump intakes, and related infrastructure, e.g., precipitates or other compounds which may foul or otherwise interfere with dewatering and/or groundwater monitoring systems.
- Significant levels of Appendix III and IV of 40 CFR part 257 or other regulated compounds which may require permitting and treatment before discharging to the environment.
- Sufficient information to inform the need for, and necessary details for completing an NPDES permit if needed.

2.7. Shape, Spatial Position, and Volume of Emplaced CCR

The spatial position, elevations, and shape of the CCR in the unit are critical factors to be determined to inform CSMs for identifying and eliminating free liquids. EPA recommends that, at a minimum, the CSM include the elements listed below, and that these elements be addressed at an appropriate level of detail to match the size and complexity of the unit and its immediate surroundings.

- Position, elevation, and shape of uppermost and lowermost surfaces of the CCR.
- Delineation of locations(s) of high-points and low areas on these surfaces.
- Map showing spatial distribution of physical and hydraulic characteristics of distinct individual CCR layers, including the basal layer and immediately surrounding materials.
- The nature of geologic or native materials surrounding the unit.

- Other information which may need to be included in the CSM based on the size and complexity of the unit and/or the status of closure activities.

2.8. Spatial Position of Water Table and Uppermost Aquifer Conditions

EPA also recommends that the CSM consider the following factors because the subsurface geology and groundwater flow can impact the rate of infiltration and releases.

- Characterization of the uppermost aquifer, consistent with the factors listed in 40 CFR 257.91(b), e.g., primary flow layers, confining, or perching layers, etc.
- Identify and delineate impermeable layers and perched zones if present.
- Identify and delineate water levels and pore-water pressure distribution within CCR unit.
- Identify and delineate elevation, position, slope, and shape of the water table at an appropriate level of resolution.
- The level of resolution needed is dependent on the variability and complexity of the CCR and surrounding subsurface geology and their associated hydraulic properties.

The information in sections 2.6-2.8 can be integrated to produce a representation of the hydraulic pressure field within and surrounding the unit using a variety of digital or analytical methods and graphical outputs. Additional factors to be considered in this regard, include those listed in following sections. It must be acknowledged that understanding additional complexity inherent to the groundwater system may be necessary to demonstrate the ability to actually eliminate free liquids (as opposed to merely temporarily removing them). The following sections represent typical types of complexities which need to be considered to form a thorough understanding of the unit and its surroundings.

Potential external factors influencing water levels including:

- Groundwater/surface water interactions.
- Surface water interactions with CCR.
- Groundwater/CCR interactions.
- Groundwater mounding.
- Groundwater sinks.
- Zones of groundwater upwelling.
- Water coming in/leaving from the sides and/or below.
- Multiple flow zones in and/or out of unit.
- Steep topography and/or complex depositional environments such as valley fill units.
- River stage temporal and spatial variability.
- Nearby production or pumping wells or other loci of groundwater extraction or recharge.
- Other factors that may affect groundwater levels or infiltration rates into the unit, such as physical barriers, nearby groundwater extraction systems, infiltration basins, hydraulic head changes from the effects nearby surface water bodies, dam releases, etc.

- Preferential pathways in/out of CCR:
    - Buried channel deposits, interconnected sand and gravel lenses and other localized zones of relatively high permeability materials.
    - Sinkholes/karst features.
    - Fractured or faulted zones in the subsurface.
    - Other natural or man-made pathways.
- Mined areas including open pits and trenches, mine spoils, coal seams, mine shafts, adits, etc.
- Engineered structures, conduits, surface or subsurface drainage features, utility trenches, or other manmade structures.
- Dams, impoundments, and related features.
- Manmade features intentionally or unintentionally functioning as subsurface drains or conduits.

2.9. <u>Determination of Volume of CCR unit containing Free Liquids</u>

If a CSM is constructed which considers and includes, as appropriate, the elements presented above, a reliable calculation of the volume of CCR containing free liquids can be estimated using modeling or other computational methods. For example, GIS or other software systems can be used to construct a model of the geometry of the CCR unit, the position of the water table in relation to the CCR unit, and all zones containing free liquids. With this modeled and/or graphical representation, and by using the tools described in the sections that follow, it may be possible to estimate the amount of free liquids in the CCR unit. The level of resolution needed to inform model inputs is dependent on the variability and complexity of the CCR and surrounding subsurface geology and their associated hydraulic properties. Other external factors, such as the overall closure design, the method(s) of dewatering, the presence of any preferential pathways, etc. could affect the reliability of the overall estimate. In most cases, any evaluation will require water level and other supporting data *from within the unit* at an appropriate spatial density to provide a level of resolution commensurate with the complexity and size of the CCR unit.

2.10. General <u>Temporal Considerations</u>

For free liquid zones above the water table, such as a locally perched water table, or for a mounded region above the water table, assessments can generally be made over short time frames based on real-time snapshot assessments of CCR. Exceptions might include situations with highly variable inputs of water to the unit from precipitation, river floodwaters, or other natural inputs. In such cases, evaluations need to consider a representative range of conditions to adequately represent site conditions.

In cases where the groundwater table is above the base of the CCR unit – continuously or periodically – a broader evaluation is needed over a longer time frame to obtain an accurate estimate of free liquids as well as to design an effective dewatering strategy. The elevation of the groundwater table typically fluctuates in response to periods of rain and drought, or river stage and/or tidal influences. Free liquids evaluations, therefore, need to consider seasonal or other temporal groundwater variations. A one-time snapshot measurement of groundwater elevations, for instance, might suggest that CCR in a particular unit are well above the water table. If free liquids were also found to be absent from the CCR themselves, such findings could support a determination of an overall absence of free liquids in the unit. However, if the water level measurements and any subsequent assessments were only taken during low water table conditions in the aquifer, the conclusions may be invalidated during wetter periods, i.e., when water table conditions are at higher elevations. For these reasons, where groundwater is a factor, a facility will typically need to assess the presence of free liquids in the context of groundwater conditions over a longer period to ensure that the relevant performance standard has been met. See, 40 CFR §§ 257.53, 257.102(d)(2)(i). EPA recommends that an evaluation time of at least one year is used to assess the water table fluctuations and potential for groundwater intrusion and saturation of CCR materials. While seasonality or other natural fluctuations are the most common concern, variations in groundwater extraction or other anthropogenic factors may also require a longer evaluation time frame.

Temporal considerations are particularly relevant for dynamic complex closure processes. Closure and installation of the cover system is often a highly dynamic process, completed in multiple phases over several years. Therefore, a single snapshot in time during closure and construction will typically not be sufficient to support a conclusive determination that free liquids have been eliminated. Identification and removal of free liquids is typically a long-term process that requires time-series or continuous data so that evolving conditions over time may be captured and evaluated.

It is EPA's understanding after reviewing several closure plans and talking with industry experts that a significant amount of dewatering is conducted in conjunction with closure. However, the primary purpose in many of those dewatering efforts appears to be primarily focused on dewatering for heavy machinery operations or so that a cover system can be installed. Partial removal of free liquids, such as dewatering efforts solely intended for installation of a cover system, does not meet the federal performance standard at 40 CFR 257.102(d)(2)(i). The elimination of free liquids is a methodical independent process that will in most cases run parallel with the construction dewatering efforts.

As a first step in this process, EPA recommends installation of a dedicated piezometer network and/or other similar instrumentation before the excavation and/or capping process begins, including monitoring elements within the CCR and within the uppermost aquifer system to enable both short term and long-term synoptic water level and free liquids measurements. It is important to note free liquids levels in piezometers may rise and fall during closure/construction. Free liquid measurements would take place throughout the closure process and would be influenced by such factors as dewatering efforts for construction purposes, compaction, and the closure of adjacent cells, as well as precipitation events. Therefore, after each significant perturbation, additional time will typically be needed for the system to return to ambient conditions so that accurate water level data can be obtained to confirm the elimination of free liquids. This presumes that free liquids within the unit are only those from past operations, such as sluicing wet CCR into the unit. However, if liquids continue to infiltrate the unit from other sources, such as groundwater, additional measures would be required to meet the performance standard. It would be inconsistent with 40 CFR 257.102(d)(2) to install a cover system in a unit that still contains free liquids. The additional measures will be unit-specific, and for these reasons, additional time should be budgeted to ensure accurate free liquids determinations prior to installing the final cover system. It may be advisable to consider automated water level recording devices to assist in free liquids determination in dynamic closure scenarios over longer time intervals. It is also worth noting that changing conditions during the ongoing closure process may necessitate dynamic work strategies including periodic abandonment of particular piezometer locations and/or adding new piezometer locations in previously unmonitored areas in response to potentially unevenly distributed dewatering performance across the unit. EPA expects such modifications to be determined through periodic evaluation of data with appropriate documentation and reporting of data-driven changes or modifications.

3. Tools and Methods for Assessment of Free Liquids

Since free liquids within the CCR unit can include surface water in the impoundment (i.e., "free water"), and readily separable porewater at a higher elevation above the local/regional water table (e.g., perched or mounded groundwater), as well as phreatic water below the regional/local water table (i.e., groundwater), the range of available diagnostic tools includes those conventionally used for groundwater assessments as well as tools and approaches tailored to characterize CCR.

Tools and methods available for free liquids assessment include direct measurement or observation methods, laboratory methods and indirect methods employing geophysical or other types of sensors. As the name implies, direct measurement/observations involve tools which enable direct identification or measurement of free liquids. For example, staff gauges, stilling wells, and V-notch weirs are examples of tools which allow for direct and/or automated observation and measurement of surface water levels in impoundments and other surface water features. In the groundwater context, standard piezometers and monitoring wells are the most common tools used for direct measurement of water levels in the saturated zone (i.e., below the water table). While surface water, i.e., "free water" needs to be addressed when present in an overall program for elimination of free liquids, this document focuses primarily on liquid within the interstitial spaces of the CCR. In this context, it is important to understand the applicability and limitations of various tools relative to the position of surface water levels, and the groundwater table. Some tools are best suited for application above the water table (e.g., *perched water*), whereas others are best applied to the saturated zone below the water table (i.e., *groundwater*).

The information below is organized and presented in terms of whether the tool allows for direct or indirect measurement of water levels, the tool's application to characterization of solid phase and/or liquid-phase materials, the tool's utility relative to the water table, and other practical considerations. Laboratory methods represent a hybrid between direct and indirect methods as field-collected (i.e., "direct") samples of in-situ materials are typically necessary for most methods, whereas actual measurements are conducted ex-situ in an off-site laboratory facility. EPA recommends direct in-situ field measurements, where possible, due to the possibility of sample degradation during handling and transportation to the laboratory (which may affect analytical results), and interferences, calibration issues, and non-unique results possible with many indirect methods. However, a robust free liquids assessment program will make appropriate use of the full range of methods, as dictated by project and site circumstances.

3.1. Temporal Considerations for Data Acquisition to Support Assessment of Free Liquids

Another important consideration for assessing free liquids is the variability and sensitivity of the system over time. EPA recommends that facilities collect time-series water level and/or pore-pressure data using in-situ field devices which have the ability to collect time-series water level information, such as automated water-level recorders in conventional piezometers or monitoring wells (e.g., pressure transducers) or vibrating wire piezometers with data logging capability. These approaches are easier to use, are more accurate, and more effectively capture temporal variability compared to approaches based on limited snapshot data.

Another temporal consideration for assessing the presence and/or elimination of free liquids concerns the variability in timeframes needed for geologic materials or CCR to recover from perturbations caused by dewatering or other activities. The time frames over which water level measurements are needed to confirm the elimination of free liquids correlates with the specific yield and specific retention properties of the CCR and geologic materials surrounding the unit, rates of liquids infiltrating into the unit from all sources, dewatering techniques used, rates and duration of dewatering efforts, etc. In all cases, it is incumbent on the owner/operator to design a program to eliminate free liquids in a manner that is demonstrable over time periods of appropriate duration. Documentation that the owner/operator has eliminated free liquids will therefore need to be conducted over a sufficient time interval to demonstrate that free liquids have been removed and have not re-infiltrated to the unit after dewatering efforts are completed.

3.2. Direct Methods

This section discusses tools and methods applicable for direct characterization of geologic and/or CCR materials as well as identification and measurement of liquids in situ, including free liquids. The list of direct methods and tools includes both quantitative and qualitative approaches. Function and application of some methods is best suited to areas of perched water above the water table or saturated materials below the water table, and some methods work equally well in either setting. While the following section describes direct methods, an overall approach which uses both direct and indirect methods can be an effective overall assessment strategy. For example, broadly applying indirect methods such as CPT (discussed in the indirect method section, below) can be effective as a first phase of investigation followed by selective application of direct methods such as standard geotechnical borings with SPT testing (discussed below) to validate and quantify assessment parameters estimated with indirect methods to produce a more robust overall assessment.

Identification of geologic layering as well as determining the physical characteristics of CCR materials can be conducted via direct observationally based methods. Excavations and trenches allow for direct visual inspection of geologic layers or CCR exposed on the excavation sidewalls. However, collection of physical samples for detailed inspection or laboratory analysis from excavations is difficult and often results in deformed samples which may no longer adequately represent the materials in their undisturbed in-situ condition. Similarly, excavations into materials containing liquids typically induces infiltration of free liquids into the excavation which inhibits visual inspection or other characterization of materials beneath the water line. However, the presence liquids and water levels in such excavations presents useful direct information pertaining to free liquids assessments, which are discussed further, below.

Advancement of standard geotechnical soil borings including collection of continuous split-spoon soil samples using the standard penetration test (SPT), enables direct inspection, characterization, and logging of subsurface materials for key parameters such as material type, grain size distribution, and related parameters. SPT is a standardized, widely accepted, commonly used and dynamic in-situ penetration test which provides a measure of penetration resistance (called blow counts or N-values) which can be correlated to the to the engineering properties of soils such as strength and density. Data collected from geotechnical soil boring employing the SPT can therefore also provide useful geotechnical information as well as affording detailed direct characterization of geology and CCR layering. Standard geotechnical borings using the standard penetration test are generally effective to characterize solid materials over the full range of saturation of the contained liquid fraction (from fully saturated to fully unsaturated materials). However, estimations of water content from soil samples collected in this manner are typically qualitative unless materials are submitted for laboratory analysis following appropriate protocols. Quantitative assessment of the degree of saturation, particularly accurate estimation of the water table surface, is best accomplished using other direct methods, discussed below.

Water levels in test pits, excavations, trenches, and boreholes can be directly observed and directly measured. The presence of free-standing water in such an excavation or boring is a direct indicator of free liquids which have drained from the pore spaces into the excavation or boring under ambient pressures and temperatures.

Descriptions of water content in soil samples from test pit or boring logs can be used to establish initial visual qualitative estimates of liquids in CCR or geologic materials at depths above and below the water table. Samples of geologic or CCR materials recovered from test pits, excavations, or borings can be visually inspected by the field geologist or engineer to estimate moisture content and degree of saturation, or submitted for laboratory analysis of grain size, moisture content or other relevant parameters. However, while useful as quick screening tools, such direct but qualitative observations by themselves do not typically provide a sufficient technical basis to accurately identify the presence, absence, or position of free liquids across a unit, because the degree of saturation is not quantifiable from direct observations of soil samples alone.

A range of standard quantitative tools are typically used to supplement initial screening observations. For example, while excavation of trenches or ditches enables direct real-time identification of free liquids by inspection of liquids within and entering the trench, water levels in such excavations can also be measured and monitored more comprehensively over wide areas via direct and/or automated methods to produce estimates of the levels, volumes, and distribution of free liquids in CCR materials at the scale of the CCR unit as a whole. However, the most basic and perhaps most versatile tool for directly assessing the presence of free liquids in the subsurface is the conventional vertical standpipe piezometer or monitoring well. Such devices (piezometers, well points, and extraction points) include a screened interval open to the subsurface materials at a particular depth which is connected to a vertical standpipe which is in turn connected to and open to the atmosphere. If there are free liquids in the pore spaces of the geologic materials or CCR into which the screen is placed, it will drain into the piezometer and the water level in the standpipe will rise to a level related to the level of saturation in the pore spaces, the percentage of interconnected pore spaces or effective porosity and permeability of the solid phase materials, temperature, atmospheric pressure, hydraulic properties and other factors. In essence, the water level in the piezometer is a direct measure of the readily separable liquids in hydraulic connection with the solid materials within the zone of influence of the piezometer and thus provide direct evidence of “free liquids.” Similarly, appropriately designed and constructed *horizontally* configured piezometers, wells or extraction points may also have a limited role in “free liquids” assessments.

Typical boreholes or wells, as either temporary or permanent installations, can be used to obtain a range of qualitative and quantitative direct measurements for a variety of hydraulic properties. For example, standard slug testing of monitoring wells can be used to directly measure hydraulic conductivity of the materials at the screened interval. Similarly, packer testing approaches can be used to directly measure transmissivity and hydraulic conductivity in open borehole bedrock installations.

Pump testing of deep and shallow groundwater monitoring wells can be used to develop quantitative direct assessments of hydraulic properties of CCR and adjacent aquifer materials, including hydraulic conductivity, transmissivity, specific yield, specific retention, etc. Pump testing which includes an assessment of responses to pumping in the pumping well as well as responses measured in nearby observation wells may also provide valuable information concerning the directional anisotropy and spatial heterogeneity of the materials affected by the test. While pumping tests are particularly important and relevant to developing site-specific dewatering strategies, approaches and designs, pump testing approaches can be conducted at different locations during earlier phases of the project to directly quantify the hydrogeologic characteristics of the site in specific areas.

3.3. Indirect Methods

The physical properties of coal ash and other CCR materials present challenges to typical characterization approaches used for commonly encountered geologic materials. For this reason, various indirect methods have gained widespread use for CCR applications. Cone penetrometer testing (CPT) technology is a widely used *indirect method* to evaluate the strength, stability, and physical and hydraulic properties of CCR to ensure safe working conditions as well as for other geotechnical and characterization objectives. For example, CPT data can also provide for a continuous profile of CCR stratigraphy, at a fine level of vertical resolution (e.g., 5-20 cm), which is especially valuable at sites with complex layering including discontinuous lenses and multiple, discrete stratigraphic horizons. Some indirect parameters measured commonly during routine CPT profiling, such as tip resistance, side friction (friction ratio), and pore pressure can inform characterization of hydraulic properties (e.g., hydraulic conductivity) and the CCR's ability to retain and release liquid. While such data can provide depth-discrete information on each distinct layer of CCR, the measurements are *indirect* as discussed below. The CPT device relies on various sensors fitted to the probe which measure tip pressure, sleeve (side) friction, porewater pressure, and other physical measurements depending on the configuration of the cone and number and type of associated sensors. These data are compiled and interpreted independently and collectively to produce *interpreted* vertical representations (i.e., profiles) of the geologic and hydraulic properties of the subsurface at each profiling location. The indirect nature of these measurements and associated interpretations are non-unique and may or may not adequately and accurately describe actual conditions. For these reasons, EPA recommends avoiding over-reliance on CPT and other indirect approaches. Rather, indirect methods should be balanced and validated with direct methods as part of an overall strategy. Acknowledging these limitations, with enough test points at appropriate test depths, the hydraulic properties of the entire CCR unit could inform the owner or operator as to appropriate locations and depths for dewatering points, estimated pumping rates, and expected time frames needed to monitor for potential recharge of free liquids after initial dewatering efforts are completed.

Similarly, vibrating wire piezometers are widely used to measure water levels and pore pressures in stilling basins and monitoring wells, monitoring dewatering systems and wick drains, as well as monitoring pore-water pressures to evaluate slope stability, dam performance, and other geotechnical objectives. Therefore, use of vibrating wire piezometers can be readily applied to free liquids assessments, especially after the hydraulic properties of the CCR unit have been characterized. While most suited to fully saturated conditions, VWPs are manufactured in many variations which enable installation in conventional boreholes or wells, grouted semi-permanently into boreholes, as well as directly inserted into shallow poorly consolidated materials. Some configurations can measure both positive and negative pressures, which could be deployed in a manner and at such depths to document the progression of dewatering at particular locations and depths.

In addition to these methods, conventional pressure transducers, typically installed in standard standpipe piezometers or monitoring wells, are in widespread use in the groundwater industry and can be used for discretized time-series monitoring of water levels and water pressure in-situ. Such devices allow for time-series recording of data at a variety of time intervals. In conjunction with commonly available telemetry systems, a network employing such recording devices, if installed at the appropriate locations and depths, can provide a comprehensive real-time water level monitoring platform.

In addition to more traditional approaches, many surface and borehole geophysical methods may have underutilized applications to free liquids assessments and/or performance monitoring of free liquids elimination efforts, as follows.

Electrical conductivity/resistivity methods for surface and borehole applications have been greatly improved over many decades. Electrical conductivity, and its reciprocal, electrical resistivity, vary predictably in relation to a soil's moisture content. Deployed in arrays of electrodes installed on the ground surface, electrical resistivity/conductivity methods can be used to effectively map subsurface regions of saturated, partially saturated, and unsaturated materials at a CCR unit based on the electrical responses. Permanently installed electrodes also may hold promise as additional fixed elements in a long-term monitoring program for free liquids. Nuclear magnetic resonance (NMR) is a useful tool to measure porosity, particularly water filled porosity in boreholes. NMR measurements/logging in boreholes could conceivably be used to enhance free liquids assessments and/or performance monitoring of free liquids elimination efforts by traditional means.

Other surface or borehole geophysical methods may hold promise as emerging methods or tools for indirectly measuring or estimating free liquids at CCR facilities.

3.4. Laboratory Methods

Field or laboratory analysis of physical samples of CCR or geologic materials can potentially be used as a tool to help identify and measure the presence of free liquids. Such laboratory methods may provide valuable data, yet the logistical difficulties of collecting a sufficient number of representative subsurface samples, including time-series data if needed, to adequately assess the presence and distribution of free liquids in-situ across a large CCR unit should be weighed in relation to other available methods, such as the installation of piezometers, to develop an effective overall approach for free liquids assessment.

Field collection of representative samples of CCR and/or geologic materials is the first step leading to laboratory analysis. Drilling of soil borings or excavation of test pits can enable collection of subsurface samples to be retained for analysis by a variety of laboratory methods. Direct inspection of such samples may provide limited qualitative assessment of free liquids present. For example, descriptions of water content in soil samples from test pit or boring logs can be used to establish initial visual qualitative estimates of liquids in CCR or geologic materials. However, such direct observations by themselves do not generally provide a sufficient technical basis to accurately identify the presence or absence of free liquids. It must also be acknowledged that the physical act of collecting a soil sample may disturb the material, thus changing its physical characteristics, which may produce laboratory analysis results that differ from actual in-situ conditions. CCR materials, particularly coal ash, are difficult to evaluate using laboratory tests for these reasons. As a consequence, EPA recommends limited reliance on laboratory analyses for making free liquids assessments.

With these limitations, some of the laboratory methods which could be included in a broader assessment of free liquids, include but are not limited to the following:

- Soil moisture content.
- Soil porosity.
- Total porosity.
- Effective porosity.
- Soil permeability.
- Hydraulic conductivity.
- Additional physical, geotechnical, and hydraulic parameters depending on site conditions and dewatering strategy.

Within the saturated zone, free liquids may be estimated based on estimates of total water content in conjunction with porosity and permeability measurements. However, the unsaturated zone and transition zone can be significantly affected by changing water levels, capillary action, etc., and are therefore better suited to direct or indirect in-situ measurements using lysimeters, soil probes, etc.

3.5. Paint Filter Liquids Test

Perhaps the most misunderstood field/lab test in relation to CCR free liquids assessments is the Paint Filter Liquids Test[1] (PFLT) whereby a sample of solid material is essentially placed into a paint filter (in the field or a laboratory) and the liquids contained within the pore spaces of the solid material are allowed to drain out into a vessel where they are measured. While this test was developed many decades ago to categorize wastes primarily for disposal purposes, it may be useful in some situations for quick screening of free liquids within CCR matrices; however, more rigorous testing is generally needed to support assessment of free liquids. While the use of the PFLT could be used as a quick screening tool, given the logistical and physical difficulties of collecting subsurface samples at necessary depths and locations for a complete site assessment of free liquids, sole reliance on the PFLT will not likely be practical or representative of conditions within the entire unit. For example, there can be physical effects from obtaining the sample at depth that could affect the representativeness of the sample (vibration, heat from the drilling bit, etc.) and could produce inaccurate results. Consequently, although it might provide relevant information to confirm the presence of water in a sample, EPA does not generally consider PFLT results to be sufficiently reliable to confirm the absence of free liquids in CCR units. EPA chose not to adopt the definition in 40 CFR 258.28(c)(1), which relies on the PFLT, or to otherwise mandate reliance on the PFLT. Therefore, EPA would not generally recommend using the PFLT, except in the context of preliminary screening.

4. Establishment and Maintenance of Monitoring Networks - Spatial and Temporal Considerations

In the CCR context, an effective monitoring network will need to include measurement devices that are effective and appropriate for assessing water levels and/or pore pressures over a range of conditions. This would typically include standard piezometers or wells (e.g., below the water table), as well as devices which are compatible with saturated, (or in some cases unsaturated) CCR materials in more localized areas (e.g. perched zones) above the water table, typically vibrating wire piezometers, as well as measurement devices designed to measure water levels in proximal surface water features if they

[1] U.S. EPA, SW-846 Test Method 9095B: Paint Filter Liquids Test.

affect the unit hydraulically (typically staff gages or stilling wells). Below, we refer to "*well network*" generically and interchangeably with "*piezometer network*", and "*monitoring network*", to include a variety of types of water level and water pressure measuring devices used collectively and concurrently to measure water levels, pore pressures, and their spatial distribution across the unit.

Monitoring networks enabling effective assessment of free liquids at the site scale will be informed by a robust CSM. Data obtained from monitoring networks provides for an understanding of aquifer properties in areas surrounding and beneath the CCR unit, as well the hydraulic and other relevant properties of the CCR itself. A piezometer network used to make a free liquids assessment should contain sufficient depth-discretized monitoring points to determine and measure vertical head gradients within the native strata and between these layers and the CCR itself at representative locations. Such vertical gradient information is important for understanding the potential for groundwater to reinfiltrate the unit. Additionally, EPA recommends that the network should include sufficient instrumentation to determine and measure groundwater/surface water interactions if they are relevant to the hydrology of the unit.

Assessment of free liquids at CCR units involves coordinated hydrologic assessment of both the CCR materials themselves and the ambient groundwater system in which the unit is located, including interactions with surface water, precipitation, sluiced water and other potential inputs and outputs. A key objective in this regard concerns determining whether the groundwater table intersects the unit and the CCR contained therein. Such assessment requires deployment of appropriate tools to measure contemporaneous hydraulic head (e.g., water levels) in all CCR and surrounding geologic media at relevant locations and depths. EPA recommends extensive use of standard piezometers and monitoring wells, as they provide direct portals to the subsurface which allow for real-time measurement of water levels indicative of free liquids. However, a robust assessment of free liquids may also include vibrating wire piezometers, and other devices, at appropriate locations and depths to determine the configuration of the water table in the area surrounding and including the unit, focusing on the region within the unit boundaries. Such a network may also include an array of vibrating wire piezometers deployed within CCR materials at various locations and depths and/or the selective use of other specialized monitoring tools such as CPT technology. Once in place, the network of piezometers and vibrating wire piezometers installed at appropriate locations and depths, based on the complexity of the CCR unit, will aid in independently assessing the effectiveness of an ongoing dewatering program. In addition to monitoring liquid levels directly at a dewatering point, data from a network of properly spaced piezometers and vibrating wire piezometers can provide a more accurate, independent, spatially robust, and complementary assessment of dewatering efforts in the intervening areas.

Free liquids may exist as CCR pore water in irregularly distributed saturated regions above the local water table elevation. Such conditions may manifest as a locally perched water table or a mounded region above the water table. In other words, there may be zones of saturation above the water table that could contain free liquids. Characterization of the CCR stratigraphy and hydraulic properties of each of the CCR layers should be conducted at sufficiently lateral and vertical spacing to identify possible localized areas of perched or mounded conditions so that free liquids may be identified and eliminated as appropriate. Well networks should include monitoring points in these zones to observe and document the dewatering process leading to elimination of free liquids.

While free liquids directly introduced to CCR impoundments or other units may exist above the water table, interactions with local groundwater should be anticipated in most cases. Understanding the relationship between the ambient water table and the CCR materials is thus essential to assessing the current and future presence of free liquids within the CCR materials.

Regarding free liquids below the water table, the size, shape and volume of the zone of intersection of the water table with the buried CCR is a key data objective. Understanding the ambient water table, especially groundwater elevations around the CCR unit is a key consideration when evaluating for the potential presence of free liquids directly in the CCR unit. To adequately measure groundwater elevations proximal to the unit, the lateral and vertical spacing of the well network must include sufficient monitoring points to enable adequate spatial resolution of the hydraulic head field within and surrounding the unit. All hydraulically relevant hydrostratigraphic zones in the uppermost aquifer system around the CCR unit should be included in the monitoring network; the number and variability of the relevant strata in the uppermost aquifer will determine the number of necessary vertical zones in need of hydraulic monitoring. Lateral spacing outside of the CCR will be dictated by the geologic complexity of the local geology. The appropriate lateral and vertical well spacing is a site-specific factor determined by the complexity of the local geology and hydrology. While modeling or other interpolation methods may be useful to calculate the volume of saturated CCR materials below the water table at a given point in time, the strength of a model is directly dependent on the well network and other data which informs it.

Similarly, lateral spacing within the CCR will be dictated by the lateral complexity of the CCR materials in-situ. There is ample evidence from site-specific studies and longstanding industry expertise to indicate that CCR materials should not be conceptualized as uniform and monolithic. Rather, both lateral and vertical variation should be expected, and the level of this complexity will dictate the number and appropriate lateral and vertical spacing of piezometers, vibrating wire piezometers or other CCR monitoring points. CPT profiling data has proven to be effective in identifying thin highly permeable zones within layered CCR materials. Understanding the hydraulic properties and spatial distribution of such zones is critical to developing an effective dewatering strategy.

Many CCR units have the benefit of previous hydrogeologic characterization data as well as existing networks of piezometers, monitoring wells, vibrating wire piezometers, etc. However, EPA has reviewed many cases where site-specific information was lacking, insufficient, or so sparse as to make such free liquids determinations highly uncertain. In these cases, additional data density is necessary. Data density determinations should be made in the context of the site conditions, CCR characteristics and depositional history, local geology, and hydrology. Some general guidelines include the following:

- Lateral spacing of water level measurement points outside or along the perimeter of the unit should be spaced sufficiently close to capture the geologic variability of the subsurface. EPA has seen numerous instances where monitoring point spacing of 200 to 300 feet would be appropriate. Distances of greater than 500 feet between data points would often be excessive unless there is clear data demonstrating little variability in the subsurface.
- Depth-discrete vertical monitoring points need to be screened or instrumented in each relevant hydrostratigraphic interval. Screened intervals greater than 10-feet should be avoided to maximize vertical discretization of head measurements. In this respect, a thick (> 10 feet) hydrostratigraphic interval may justify more than one screened zone at different elevations. It

should be noted that for removal purposes, it is critical to understand what specific layers are contributing free liquids.

- Preferential pathways such as channel features, weathered rock zones, fracture zones within bedrock, etc. would require additional focused water level measurement points.
- Water level/pore pressure monitoring points in CCR materials should generally be installed in a sufficiently dense pattern to differentiate between hydraulically disconnected zones which may contribute little free liquids from more permeable regions within the CCR.
- Depth control and discretization vertically in CCR units needs to consider the thickness, lateral and vertical variability of the materials, and the presence of localized or widespread features such as impermeable layers, lenses, or wedge-shaped bodies (e.g., 'deltas' within the CCR). Sufficient monitoring points are needed in the vertical dimension to enable identification of perched or hydraulically isolated zones should they exist. In cases where the saturated thickness of CCR is greater than the vertical zone targeted by existing monitoring wells, additional vertical monitoring points may be needed.
- Depending on the geology of the area, it may be necessary to install depth-discrete vertical monitoring points into the undisturbed geologic materials beneath the CCR to determine whether upward vertical gradients are present beneath the waste.
- Networks should also include surface water gaging stations (e.g., paired staff gages and shallow piezometers, stilling wells, etc.), for all relevant surface water features that can affect the presence and removal of free liquids within the unit.

It is important to ensure the appropriate development of all wells and piezometers emplaced at CCR units. For those installations placed in CCR materials particular care will be needed during development to avoid plugging to ensure water level measurements are representative of the free liquids within the adjacent CCR materials.

5. Tools for Elimination or Removal of Free liquids

In situations where groundwater interactions are a reality, the difficulty of sustained elimination of free liquids in contact with groundwater needs to be acknowledged and factored into engineering and construction plans. The particular engineering and construction methods used for dewatering will have an influence on the approach and tools used for measuring water levels and documenting sustained effective removal of free liquids.

An effective demonstration of the elimination of free liquids should consider all available industry-standard dewatering technologies and employ both short- and long-term tools that are best suited for specific site situations. Tools typically used to eliminate free liquids prior to excavation and removal of CCR materials, installation of a cover system, etc., include but are not limited to the following:

- Rim ditches: Long-arm excavators typically dig long linear trenches which enable gravity drainage, collection, and removal of free liquids from adjacent CCR materials. Pumps of various types may be used to assist in removal of liquids from the trenches. Trench depths are typically on the order of 10-20 feet or less, depending on the properties of the CCR, e.g., stability, reach of the excavator, etc. Networks of horizontally excavated trenches may be connected to vertical sumps to facilitate groundwater extraction. Where free liquids exist below the reach of the excavator, a sequential approach of dewatering followed by CCR removal may be used to excavate CCR in successive lifts. Depending on site-specific conditions, this method may be used in conjunction with other dewatering methods such as the use of deep groundwater extraction wells and shallow vacuum extraction systems.

- Vacuum-extraction using arrays of manifolded well points. The spacing and number of such well points is dependent on the characteristics of the CCR materials. This method is used for shallow dewatering operations. The effective depth of this technology is limited to the suction limit, typically on the order of 20 feet or less. In areas beneath the effective range of the vacuum array, a sequential approach of dewatering followed by CCR removal may be used to excavate CCR in successive lifts. Extraction points may then be redeployed to successively dewater the next deeper interval of material. Excavation and dewatering may be used in this fashion to dewater and remove the full thickness of CCR.
- Groundwater extraction: Deeper vertical or horizontal wells may be employed for groundwater extraction in deeper portions of the CCR materials (i.e., below the suction limit) and/or the adjacent aquifer materials.

Pilot testing of deep and shallow groundwater extraction systems, e.g., conducting pumping tests of limited durations, may provide invaluable data which can inform dewatering strategies and system design. Pump testing of in-situ CCR materials is most valuable in this regard as results from such tests are directly transferrable to and scalable to specific dewatering approaches and designs at the unit scale. In addition, pumping tests can provide quantitative information concerning the hydraulic properties of the materials, including hydraulic conductivity, transmissivity, specific yield, and specific retention. Additionally, depending on test design, pilot-scale pumping tests may inform directional anisotropies and other variability in the materials. Such information may provide critical insights into dewatering strategies and system design at full scale.

5.1. Typical Dewatering Programs May Use Some or All of These Methods in a Coordinated Fashion

Once free liquids appear to have been removed from a unit, additional tools may be applied to create an environment in which the elimination of free liquids may be confidently sustained over the longer term, especially when CCR is initially in contact with the groundwater table. These tools involve hydraulic manipulation, source containment, or other means of effectively isolating waste from further interactions with water (precipitation, groundwater, etc). These include, but are not limited to the following:

- Waste consolidation or other modifications of CCR footprint, e.g., removal of CCR beneath the water table and placing it in engineered capped containment cells above the zone of water table fluctuation.
- Underdrains: Used to remove infiltrating groundwater to maintain groundwater levels beneath the base of CCR. Can be passive gravity-driven and/or pump-assisted systems depending on what works best for sustained removal.
- Groundwater extraction: Hydraulic manipulation used to affect sustained removal of groundwater from the region surrounding and beneath the CCR footprint to prevent groundwater from re-infiltrating the unit from any direction.
- Vertical barriers (slurry walls, etc.): When installed correctly, vertical barriers may be effective in controlling lateral movement of liquids to effectively isolate CCR from external groundwater or other liquids. It is typically necessary to key a vertical barrier into an effective and laterally

contiguous low permeability confining layer below the base of the unit to prevent infiltration of liquids at the base of the barrier. May be used in conjunction with groundwater extraction.

- Binding agents and in-situ stabilization of waste (ISS): Such methods encase CCR in solid impermeable materials which effectively provides long-term isolation of CCR from adjacent groundwater and other liquids.

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