Assessment of Corrective Measures
OGS Ash Pond

Ottumwa Generating Station
Ottumwa, Iowa

Prepared for:

Alliant Energy

SCS ENGINEERS

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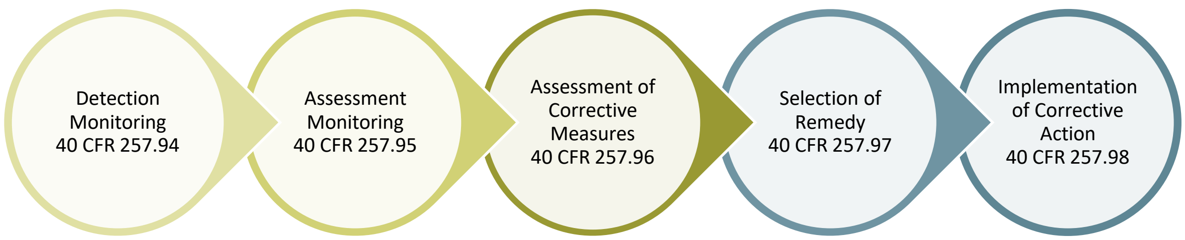
EXECUTIVE SUMMARY

Interstate Power and Light Company (IPL), an Alliant Energy company, operates two ash ponds at the Ottumwa Generating Station (OGS). The ponds are used to manage coal combustion residuals (CCR) and wastewater from the power plant, which burns coal to generate electricity.

IPL samples and tests the groundwater in the area of the ash ponds to comply with U.S. Environmental Protection Agency (USEPA) standards for the Disposal of CCR from Electric Utilities, or the “CCR Rule” (Rule).

Groundwater samples from two of the wells installed to monitor one of the ponds (OGS Ash Pond) contain cobalt at levels higher than the Groundwater Protection Standards (GPS) defined in the Rule. Cobalt occurs naturally and can be present in coal and CCR.

IPL has prepared this Assessment of Corrective Measures (ACM) Report in response to the groundwater sampling results at the OGS facility. The ACM process is one step in a series of steps defined in the Rule and shown below.



To prepare the ACM, IPL has worked to understand the following:

- Types of soil and rock deposits in the area of the OGS facility.
- Depth of groundwater.
- Direction that groundwater is moving.
- Potential sources of the cobalt in groundwater.
- The area where cobalt levels are higher than the USEPA standards.
- The people, plants, and animals that may be affected by levels of cobalt in groundwater that are above the GPS.

IPL has installed new wells to help identify where cobalt levels are higher than the USEPA standards. Because the time allowed by the Rule to prepare the ACM is limited, work to improve the understanding of the items listed above is still ongoing.

IPL has identified appropriate options, or Corrective Measures, to bring the levels of cobalt in groundwater below USEPA standards. In addition to stopping the discharge of CCR and OGS wastewater to the pond, these corrective measures include:

- Cap CCR in Place with Monitored Natural Attenuation (MNA)
- Consolidate CCR and Cap with MNA
- Excavate and Dispose CCR on Site with MNA
- Excavate and Dispose CCR in Off-site Landfill with MNA

IPL has also included a "No Action" alternative for comparison purposes only.

The ACM includes a preliminary evaluation of all five options using factors identified in the Rule.

Based on what is currently known, the groundwater impacts at OGS are limited, but are not completely understood. IPL will continue to work on understanding groundwater impacts at OGS, and will use this information to select one of the Corrective Measures identified above.

IPL will provide semiannual updates on its progress in evaluating Corrective Measures to address the groundwater impacts at OGS.

Before a remedy is selected, IPL will hold a public meeting with interested and affected parties to discuss the ACM.

For more information on Alliant Energy, view our 2019 Corporate Sustainability Report at http://www.alliantenergy.com/sustainability.

1.0 INTRODUCTION AND PURPOSE

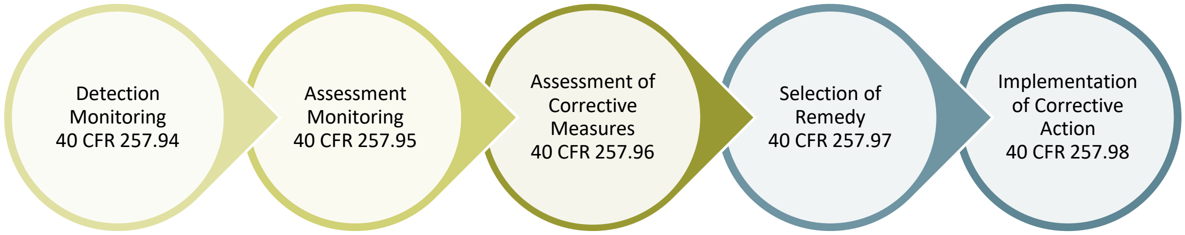
The Assessment of Corrective Measures (ACM) at the Interstate Power and Light Company (IPL) Ottumwa Generating Station (OGS) was prepared to comply with U.S. Environmental Protection Agency (USEPA) regulations regarding the Disposal of Coal Combustion Residuals (CCR) from Electric Utilities [40 CFR 257.50-107], or the "CCR Rule" (Rule). Specifically, the ACM was initiated and this report was prepared to fulfill the requirements of 40 CFR 257.96, including:

- Prevention of further releases
- Remediation of release
- Restoration of affected areas

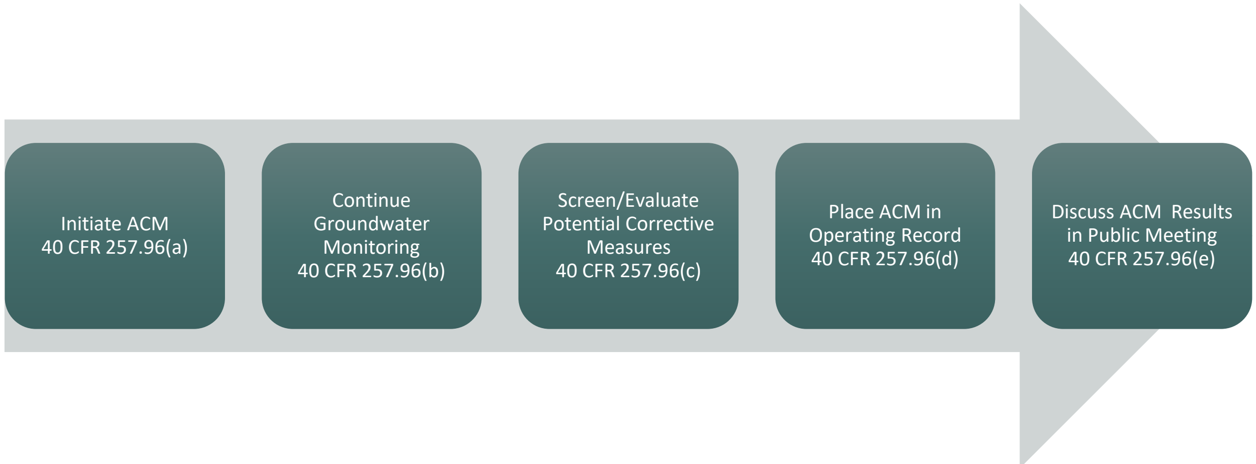
This ACM Report summarizes the remedial alternatives for addressing the Groundwater Protection Standard (GPS) exceedances observed in the October 2018 sampling event for the OGS Ash Pond, and identified in the Notification of Groundwater Protection Standard Exceedance dated January 14, 2019.

1.1 ASSESSMENT OF CORRECTIVE MEASURES REQUIREMENTS

As discussed above, this ACM Report has been prepared in response to GPS exceedances observed in groundwater samples collected at the OGS facility. The ACM process is one step in a series of steps defined in the CCR Rule and depicted in the graphic below. To date, IPL has implemented a detection monitoring program per 40 CFR 257.94 and completed assessment monitoring at OGS per 40 CFR 257.95. An ACM is now required based on the groundwater monitoring results obtained through October 2018. With the ACM completed, IPL is required to select a corrective measure (remedy) according to 40 CFR 257.97. The remedy selection process must be completed as soon as feasible, and, once selected, IPL is required to start the corrective action process within 90 days.



The process for developing the ACM is defined in 40 CFR 257.96 and is shown in the graphic below. IPL is required to discuss the ACM results in a public meeting at least 30 days before selecting a remedy. To facilitate the selection of a remedy for the GPS exceedances at OGS, IPL continues to investigate and assess the nature and extent of the groundwater impacts. Information about the site, the groundwater monitoring completed, the groundwater impacts as they are currently understood, and the ongoing assessment activities are discussed in the sections that follow.



1.2 SITE INFORMATION AND MAP

OGS is located southwest of the Des Moines River, approximately 8 miles northwest of the City of Ottumwa in Wapello County, Iowa (**Figure 1**). The address of the plant is 20775 Power Plant Road, Ottumwa, Iowa. In addition to the coal-fired generating station, the property also contains the OGS Ash Pond, the OGS Zero Liquid Discharge (ZLD) Pond, a coal stockpile, and a hydrated fly ash stockpile.

The two CCR units at the facility (OGS Ash Pond and OGS ZLD Pond) are each monitored with single-unit groundwater monitoring systems. The OGS Ash Pond is the subject of this ACM Report.

The pending closure of the OGS Ash Pond was discussed in the IPL Notification of Intent to Close CCR Surface Impoundment, dated April 3, 2019. A map showing the CCR units and all background (or upgradient) and downgradient monitoring wells with identification numbers for the CCR groundwater monitoring program is provided as **Figure 2**.

2.0 BACKGROUND

2.1 REGIONAL GEOLOGIC INFORMATION

The uppermost geologic formation beneath OGS that meets the definition of the "uppermost aquifer," as defined under 40 CFR 257.53, is the Mississippian bedrock aquifer and hydraulically connected overlying unconsolidated sediments. The thickness and water-producing capacity of the unconsolidated material in the area is variable. A summary of the regional hydrogeologic stratigraphy is included in **Attachment A.**

2.2 SITE GEOLOGIC INFORMATION

Monitoring wells MW-301 through MW-306 were installed to intersect the uppermost aquifer at the site. Due to variations in the unconsolidated material thickness and the bedrock surface, some wells are screened in unconsolidated material and some are in bedrock. The unconsolidated material at these well locations generally consists of a clay layer overlying clay and sand. The total monitoring well boring depths are between 14 and 50 feet. The depth to bedrock at the site is variable, and the bedrock surface is highly weathered in some areas. Bedrock was encountered as shallow as 7 feet and as deep as 44 feet below ground surface (bgs) in the monitoring well borings. The boring logs for MW-301 through MW-306 are included in **Appendix B.**

Shallow groundwater at the site generally flows toward the Des Moines River. The groundwater flow pattern in April 2019 is shown on **Figure 3**. The groundwater elevation data for the CCR monitoring wells are provided in **Table 1**.

A geologic cross section was prepared for OGS. The cross section line runs through upgradient well MW-301 and downgradient monitoring wells MW-306 and MW-307, and crosses the OGS Ash Pond. The cross section location is provided on **Figure 2**, and the geologic cross section is provided on **Figure 4**. Geologic material and estimated water table levels are identified on the cross section.

2.3 CCR RULE MONITORING SYSTEM

The groundwater monitoring system established in accordance with the CCR Rule consists of one upgradient (background) monitoring well and five downgradient monitoring wells. The CCR Rule wells are installed in the uppermost aquifer at the site. Well depths range from approximately 14 to 50 feet bgs.

The background well, MW-301, and five downgradient wells, MW-302, MW-303, MW-304, MW-305, and MW-306, were installed in November and December 2015.

3.0 NATURE AND EXTENT OF GROUNDWATER IMPACTS

3.1 POTENTIAL SOURCES

The potential sources of groundwater impacts detected in the Ash Pond monitoring system are currently under evaluation. The Closure Plan for CCR Surface Impoundments at OGS issued in September 2016 details the steps to be undertaken to close the OGS Ash Pond by leaving the CCR in place, in accordance with §257.102(b) of the CCR Rule. Based on the Closure Plan, potential sources of groundwater impacts from the Ash Pond CCR unit include the following:

CCR Unit	Potential Sources	Description	Quantity
OGS Ash Pond	CCR	Bottom ash, economizer ash, precipitator fly ash, hydrated fly ash, and pyrites	463,000 CY to this total
	Storm water	Annual precipitation, runoff from surrounding areas	94 AC-FT. (Watershed of 76 acres)
	Low-volume plant wastewater	Discharge from the oil water separator, SCU blowdown, plant drains, cooling tower blowdown, and contact water/leachate from OML	1.62 million gallons per day (MGD)

Note: Storm water volume is calculated based on the watershed area for the OGS Ash Pond and the annual average precipitation for Ottumwa, Iowa, of 37 inches/year. The volume of annual runoff from the surrounding areas that are not open water (58 acres), which are part of the OGS Ash Pond watershed, is estimated using Figure 1. Average Annual Runoff, 1951-1980 from USGS publication Average Annual Runoff in the United States, 1951-80 (Gebert 1987). Figure 1 shows approximately 8.0 inches of runoff from the 58 acres for an estimated 39 acre-feet of storm water annually. The quantity provided for plant wastewater is the average discharge from the ash pond (Outfall 001).

The OGS ZLD Pond is monitored separately from the Ash Pond and is not currently considered a potential source for the groundwater impacts detected in the Ash Pond monitoring system.

3.2 GROUNDWATER ASSESSMENT

3.2.1 Groundwater Depth and Flow Direction

Depth to groundwater as measured in the site monitoring wells varies from 1 to 25 feet bgs due to topographic variations across the facility and seasonal variations in water levels. Groundwater flow at the site is generally to the east-northeast, and the groundwater flow direction and water levels fluctuate seasonally due to the proximity to the river.

3.2.2 Groundwater Protection Standard Exceedances Identified

The ACM process was triggered by the detection of cobalt at statistically significant levels exceeding the Groundwater Protection Standards (GPSs) in samples from MW-305.

This statistical evaluation of the assessment monitoring results was based on the first four sampling events for the Appendix IV assessment monitoring parameters, including complete sampling events in April, August, and October 2018, and a resampling event for cobalt at selected wells in January 2019. The complete results for these sampling events are summarized in **Table 3**.

For comparison of assessment monitoring data to fixed GPS values, the USEPA's Unified Guidance for Statistical Analysis of Groundwater Monitoring Data at RCRA Facilities (EPA 530-R-09-007, March 2009) recommends the use of confidence intervals. Specifically, the suggested approach for comparing assessment groundwater monitoring data to GPS values based on long-term chronic health risk, such as drinking water Maximum Contaminant Levels (MCLs), is to compare to a lower confidence limit around the arithmetic mean with the fixed GPS.

The calculated lower confidence limit for the means were compared to the cobalt GPS for wells MW-305 and MW-306. Based on these comparisons, a statistically significant exceedance has not occurred for cobalt at MW-306. Monitoring well MW-306 had individual results exceeding the GPS for cobalt, but the exceedances were not determined to be at statistically significant levels.

Based on the results of assessment monitoring conducted through the April 2019 sampling event, statistically significant levels exceeding the GPSs were identified for the following well and parameter:

Assessment Monitoring Appendix IV Parameters	Location of GPS Exceedance(s)	Historic Range of Detections at Wells Exceeding GPS	Groundwater Protection Standards (GPS)
Cobalt (µg/L)	MW-305	14.5-17.2	6

µg/L = micrograms per liter

Note: Historic range includes results from assessment monitoring from April 2018 through April 2019.

3.2.3 Expanding the Groundwater Monitoring Network

Monitoring wells MW-310 and MW-311 were installed in the area between the current downgradient wells and the Des Moines River to fulfill the requirements of 40 CFR 257.95(g)(1), which requires additional characterization to support a complete and accurate assessment of corrective measures. The installation of these wells was originally scheduled for spring 2019, but due to state and federal permitting requirements and persistent flooding along the Des Moines River, the installation was delayed. The new wells have been installed and developed, but the initial sampling of these wells has not been completed as of the date of this report. The full schedule of groundwater samples collected to date is provided in Table 2.

3.3 CONCEPTUAL SITE MODEL

The following conceptual site model describes the compound and nature of the constituent above the GPS, discusses potential exposure pathways affecting human health and the environment, and presents a cursory review of their potential impacts. The conceptual site model for OGS has been prepared in general conformance with the Standard Guide for Developing Conceptual Site Models for Contaminated Sites (ASTM E1689-95). This conceptual site model is the basis for assessing the efficacy of likely corrective measures to address the source, release mechanisms, and exposure routes.

3.3.1 Nature of Constituent Above GPS

To describe the nature of the constituents in groundwater at OGS, we have reviewed a number of sources for information regarding cobalt in groundwater, and how that groundwater may impact potential receptors through the exposure pathways discussed in Section 3.3.2.

Cobalt

Cobalt (Co) is a naturally occurring element that has properties similar to those of iron and nickel (ATSDR 2004). Cobalt is naturally present in coal and is present in CCR after the coal is combusted.

Cobalt is commonly used to create blue pigment and coloration in jewelry, glass, metal, and other decorative uses. Industrially, Cobalt is primarily used in the manufacture of magnetic, wear-resistant and high-strength alloys (Campbell, 2008).

A summary of the properties, occurrences, and potential health effects of cobalt is provided in the Public Health Statement and ToxFAQs factsheet prepared by the Agency for Toxic Substances and Disease Registry (ATSDR), which is an agency of the U.S. Department of Health and Human Services. Copies of the ATSDR Public Health Statement and ToxFAQs factsheet are provided in **Appendix C.**

Cobalt Exposure

In January 2016, the United States Department of Health and Human Services (HHS) ATSDR provided a health consultation to the United States Department of HHS (ATSDR 2016). The report offered the following:

- Cobalt is an essential nutrient that humans need in small amounts for maintenance of vitamin B12 (TOX, 2008). However, when consumed in high amounts, cobalt can adversely affect the blood, liver, kidneys, and heart.
- Studies in animals suggest that exposure to high amounts of cobalt during pregnancy can affect the health of the developing fetus, but doses used in these studies were much higher than the amounts to which humans are usually exposed (ATSDR 2004). Birth defects have not been found in human children born to mothers who were treated with cobalt during pregnancy. Cardiomyopathy has been reported in humans exposed to cobalt, but these effects may have been confounded by the alcoholism of the patients. Much larger doses of cobalt were required to induce the same effects in animal studies (ATSDR, 2004).
- The International Agency for Research on Cancer (IARC) determined that certain forms of cobalt have been classified as possibly carcinogenic to humans (IARC, 2006), but cobalt has not been found to cause cancer in humans or animals following exposure in food or water. Studies indicate that cobalt is a potential carcinogen when inhaled.
- Animal studies suggest that children may absorb more cobalt than adults from food and liquids. It is estimated that humans absorb 5 to 45 percent of ingested cobalt (TOX, 2008).

The concentrations of cobalt detected to date in samples from the site monitoring wells range from below the detection limit to 17.2 µg/L. The GPS for cobalt is 6 µg/L. For drinking water, the USEPA has not established a maximum contaminant level (MCL) for cobalt. Based on the preamble to the CCR Rule amendments issued in the Federal Register (Volume 83, No. 146) on July 30, 2018, USEPA established the GPS for cobalt using guidelines for assessing human health risks for environmental pollutants. The GPS represents a concentration that people could be exposed to daily for a lifetime without negative effects (USEPA, 2018).

3.3.2 Potential Receptors and Pathways

As described in **Section 3.3**, ASTM E1689-95 provides a framework for identifying potential receptors (people or other organisms potentially affected by the groundwater impacts at OGS) and pathways (the ways groundwater impacts might reach receptors). In accordance with ASTM E1689-95, we have considered potential human and ecological exposures to groundwater impacted by the constituents identified in **Section 3.2.2**:

Human Health

In general, human health exposure routes to contaminants in the environment include ingestion, inhalation, and dermal contact with the following environmental media:

- Groundwater
- Surface Water and Sediments
- Air
- Soil
- Biota/Food

If people might be exposed to the impacts described in **Section 3.0** via one of the environmental media listed above, a potential exposure route exists and is evaluated further. For the groundwater impacts at OGS, the following potential exposure pathways have been identified with respect to human health:

- Groundwater – Ingestion and Dermal Contact: The potential for ingestion of, or dermal contact with, impacted groundwater from OGS exists if water supply wells are present in the area of impacted groundwater and are used as a potable water supply. Based on a review of the Iowa Department of Natural Resources GeoSam well database, and information provided by OGS:
  - No off-site water supply wells have been identified downgradient or sidegradient in the vicinity of the CCR units.
  - Potable water is not supplied from on-site wells. Potable water at OGS is provided by the Wapello Rural Water Association.

- Surface Water and Sediments – Ingestion and Dermal Contact: The potential for ingestion of or dermal contact with impacted surface water and sediments exists if impacted groundwater from the OGS facility has interacted with adjacent surface water and sediments, to the extent that cobalt is present in these media at concentrations that represent a risk to human health.

- Biota/Food – Ingestion: The potential for ingestion of impacted food exists if impacted groundwater from the OGS facility has interacted with elements of the human food chain. Elements of the food chain may also be exposed indirectly through groundwater-to-surface water interactions, which are subject to additional assessment.

Based on the lack of groundwater exposure, only the surface water, sediment, and biota/food exposure pathways were retained for further consideration until the nature and extent of cobalt impacts via groundwater have been evaluated with additional monitoring wells. If the impacts do not extend to the river, then the surface water and sediment pathways will not be complete. Implementation of potential corrective measures may introduce secondary exposure pathways that are discussed in **Section 6.0** and will be evaluated further as a corrective measure is selected for OGS.

Ecological Health

In addition to human exposures to impacted groundwater, potential ecological exposures are also considered. If ecological receptors might be exposed to impacted groundwater, the potential exposure routes are evaluated further. Ecological receptors include living organisms, other than humans, the habitat supporting those organisms, or natural resources potentially adversely affected by CCR impacts. This includes:

- Transfer from an environmental media to animal and plant life. This can occur by bioaccumulation, bioconcentration, and biomagnification.

  - Bioaccumulation is the general term describing a process by which chemicals are taken up by a plant or animal either directly from exposure to impacted media (soil, sediment, water) or by eating food containing the chemical.

  - Bioconcentration is a process in which chemicals are absorbed by an animal or plant to levels higher than the surrounding environment.

  - Biomagnification is a process in which chemical levels in plants or animals increase from transfer through the food web (e.g., predators have greater concentrations of a particular chemical than their prey).

- Benthic invertebrates within adjacent waters.

Based on the information presented in **Section 3.2.3** and the location of the Des Moines River downgradient from the current area of known groundwater impacts, both of these ecological exposure routes need to be evaluated further.

Both potential ecological exposure pathways require groundwater-to-surface water interactions for the exposure pathway to be complete. The groundwater-to-surface water interactions at OGS are the subject of ongoing assessment.

The surface water/sediment, biota/food, and ecological exposure assessment is presently incomplete as the extent of groundwater impacts is still being evaluated. If groundwater impacts extend to the river, then these exposure pathways will be evaluated further.

4.0 POTENTIAL CORRECTIVE MEASURES

In this section, we identify potential corrective measures to meet the ACM goals identified in 40 CFR 257.96(a), which are to:

- Prevent further releases
- Remediate releases
- Restore affected areas to original conditions

The development of corrective measure alternatives is described further in the following sections. Corrective measure alternatives developed to address the groundwater impacts at OGS are described in **Section 5.0**. The alternatives selected are qualitatively evaluated in **Section 6.0**.

4.1 IDENTIFICATION OF CORRECTIVE MEASURES

As described in the USEPA Solid Waste Disposal Facility Criteria Technical Manual (USEPA 1998), corrective measures generally include up to three components, including:

- Source Control
- Containment
- Restoration

Within each component, there are alternative measures that may be used to accomplish the component objectives. The measures from one or more components are then combined to form corrective measure alternatives (discussed in **Section 5.0**) intended to address the observed groundwater impacts. Potential corrective measures were identified based on site information available during development of the ACM for the purpose of meeting the goals described in **Section 4.0**.

Each component and associated corrective measures are further identified in subsequent paragraphs. The corrective measures are evaluated for feasibility and combined to create the corrective action alternatives identified in this section, and further evaluated in **Section 5.0**. We continue to evaluate site conditions and may identify additional corrective measures based on new information regarding the nature and extent of the impacts.

4.1.1 Source Control

The source control component of a corrective measure is intended to identify and locate the source of impacts and provide a mechanism to prevent further releases from the source. For the OGS site, the sources to be controlled are the CCR materials in the OGS Ash Pond and the associated process water. Each of the source control measures below require closure of the impoundment, and for waste water to be re-directed from the CCR unit to eliminate the flows that may mobilize constituents from the CCR and transport them to groundwater. We have identified the following potential source control measures:

- **Close and cap in place.** Close the OGS Ash Pond and cap the CCR in place to reduce the infiltration of rain water into the impoundment, and prevent transport of CCR constituents from unsaturated CCR materials into the groundwater, and minimize the potential for CCR to interface with groundwater.

- **Consolidate and cap.** Consolidate CCR from the OGS Ash Pond into one or two areas to reduce the potential source footprint, prevent transport of CCR constituents from unsaturated CCR materials into the groundwater, and reduce the potential for CCR to interface with groundwater.

- **Excavate and create on-site disposal area.** Excavate and place CCR in a newly lined landfill area on site to prevent further releases from the OGS Ash Pond and isolate the CCR from potential groundwater interactions. Cap the new landfill with final cover to prevent the transport of CCR constituents from unsaturated CCR.

- **Excavate and dispose at a licensed off-site disposal area.** Remove all CCR from the OGS Ash Pond and haul it to a licensed landfill to prevent further releases from the CCR areas.

Water movement through the CCR materials is the mechanism for CCR impacts to groundwater, including surface water that moves vertically through the CCR materials via infiltration of precipitation and surface water runoff.

Based on the available information for this site, all the source control measures have potential to prevent further releases caused by infiltration, thus are retained for incorporation into alternatives for further evaluation. However, IPL continues to investigate the source of groundwater impacts and, with new information, source control measures may be added or removed from consideration.

4.1.2 Containment

The objective of containment is to limit the spread of the impacts beyond the source. The need for containment depends on the nature and extent of impacts, exposure pathways, and risks to receptors. Containment may also be implemented in combination with restoration as described in **Section 4.1.3**.

Containment may be a recommended element of a corrective measure if needed to:

- Prevent off-site migration of groundwater impacts
- Cease completion of an exposure pathway (e.g., water supply well)

Containment may also be used in lieu of active restoration if an active approach is needed but treatment is not warranted by the aquifer characteristics including:

- Water in the affected aquifer is naturally unsuited for human consumption.
- Contaminants present in low concentration with low mobility.
- Low potential for exposure to contaminants and low risk associated with exposure.
- Low transmissivity and low future user demand.

The following measures have potential to limit the spread of continued or remaining groundwater impacts:

- **Gradient Control with Pumping.** Gradient control includes a measure to alter the groundwater velocity and direction to slow or isolate impacts. This can be accomplished with pumping wells and/or a trench/sump collection system. If groundwater pumping is considered for capturing an impacted groundwater plume, the impacted groundwater must be managed in conformance with all applicable Federal and State requirements.

- **Gradient Control with Phytotechnology**. Gradient control with phytotechnology relies on the ability of vegetation to evapotranspire sources of surface water and groundwater. Water interception capacity by the aboveground canopy and subsequent evapotranspiration through the root system can limit vertical migration of water from the surface downward. The horizontal migration of groundwater can be controlled or contained using deep-rooted species, such as prairie plants and trees, to intercept, take up, and transpire the water. Trees classified as phreatophytes are deep-rooted, high-transpiring, water-loving organisms that send their roots into regions of high moisture and can survive in conditions of temporary saturation.

- **Chemical Stabilization.** Stabilization refers to processes that involve chemical reactions that reduce the leachability of cobalt. Stabilization chemically immobilizes impacts or reduces their solubility through a chemical reaction. The desired results of stabilization methods include converting metals into a less soluble, mobile, or toxic form.

Based on the currently available information for this site, active containment (other than source control) is not included in the proposed alternatives. IPL will continue to investigate the nature and extent of the groundwater impacts at OGS and may add containment measures as warranted by data.

4.1.3 Restoration

Restoration is the process through which groundwater quality is restored to meet GPSs. This can be accomplished by way of Monitored Natural Attention (MNA) or intensively addressed by groundwater treatment with or without extraction.

MNA can be a viable remedy or component of a remedial alternative for groundwater impacted with metals. MNA requires ongoing involvement and potentially intense characterization of the geochemical environment to understand the attenuation processes involved, and to justify reliance on them and regular, long-term monitoring to ensure the attenuation processes are meeting remedial goals.

MNA is not a “do-nothing” alternative; rather it is an effective knowledge-based remedy where a thorough engineering analysis provides the basis for understanding, monitoring, predicting, and documenting natural processes. To properly employ this remedy, there needs to be a strong scientific basis supported by appropriate research and site-specific monitoring implemented in accordance with quality controls. The compelling evidence needed to support proper evaluation of the remedy requires that the processes that lower metal concentrations in groundwater be well understood.

If active treatment is implemented, water may be treated in-situ, on site, or off site. The need for active treatment depends on the nature and extent of impacts, potential exposure pathways, and current and anticipated future risks to receptors. If there are no receptors or if the risks are acceptably low, then MNA is an appropriate option. If existing or future risks require a more rapid restoration of groundwater quality, then active restoration may be needed.

Treated groundwater may be re-injected, sent to a local publicly owned treatment works (POTW), or discharged to a local body of surface water, depending on local, state, and federal requirements. Typical on-site treatment practices for metals include coagulation and precipitation, ion exchange, or reverse osmosis. Off-site wastewater treatment may include sending the impacted groundwater that is extracted to a local POTW or to a facility designed to treat the contaminants of concern.

The removal rate of groundwater constituents such as cobalt will depend on the rate of groundwater extraction, the cation exchange capacity of the soil, and partition coefficients of the constituents sorbed to the soil. As the concentration of metals in groundwater is reduced, the rate at which constituents become partitioned from the soil to the aqueous phase may also be reduced. The amount of flushing of the aquifer material required to remove the metals and reduce their concentration in groundwater below the GPS will generally determine the time frame required for restoration. This time frame is site-specific.

In-situ methods may be appropriate, particularly where pump and treat technologies may present adverse effects. In-situ methods may include biological restoration requiring pH control, addition of specific micro-organisms, and/or addition of nutrients and substrate to augment and encourage degradation by indigenous microbial populations. Bioremediation requires laboratory treatability studies and pilot field studies to determine the feasibility and the reliability of full-scale treatment.

Based on current information, MNA is retained for incorporation into alternatives for further evaluation. Other restoration measures are not currently required for this site, but may be added following continued investigation of the nature and extent of groundwater impacts.

5.0 CORRECTIVE MEASURE ALTERNATIVES

We have preliminarily identified the following corrective measure alternatives for the groundwater impacts at OGS:

- Alternative 1 – No Action
- Alternative 2 – Close and Cap in Place and MNA
- Alternative 3 – Consolidate On Site and Cap with MNA
- Alternative 4 – Excavate and Dispose On Site with MNA
- Alternative 5 – Excavate and Dispose Off Site with MNA

These alternatives were developed by selecting components from the reasonable and appropriate corrective measures components discussed above. With the exception of the No Action alternative, each of the corrective measure alternatives meet the requirements in 40 CFR 257.97(b)(1) through (5) based on the information available at the current time. We may identify additional alternatives based on the continued evaluation of site conditions.

5.1 ALTERNATIVE 1 – NO ACTION

IPL is committed to implementing corrective measures as required under the Rule, and the No-Action alternative is included as a baseline condition and a point of comparison for the other alternatives. The consideration of this alternative assumes the monitoring of groundwater continues under this action.

5.2 ALTERNATIVE 2 – CLOSE AND CAP IN PLACE WITH MNA

Alternative 2 includes closing the OGS Ash Pond (no further discharge), covering the CCR materials with a cap, and establishing vegetation in accordance with the requirements for closure in place in 40 CFR 257.102(d). This measure is consistent with landfill cover systems to prevent infiltration of surface water into the CCR as described in **Section 4.1.1**. The capped areas will be subject to enhanced groundwater monitoring via MNA.

This alternative eliminates CCR sluicing/plant process water discharges and, with the installation of a cap, will reduce infiltration through the CCR. This is expected to address the major contributor to the observed GPS exceedances, which is exposure of CCR material to precipitation/surface water infiltration. Further leaching of metals and migration within groundwater will be reduced and may be eliminated over time. MNA is included with this alternative to monitor changes in groundwater impacts and the effectiveness of degradation mechanisms on groundwater concentrations over time.

5.3 ALTERNATIVE 3 – CONSOLIDATE ON SITE AND CAP WITH MNA

Alternative 3 includes closing the OGS Ash Pond (no further discharge), relocating and consolidating CCR into a smaller footprint within the CCR surface impoundments, covering the CCR materials with a cap, and establishing vegetation in accordance with the requirements for closure in place in 40 CFR 257.102(d). This measure is consistent with landfill cover systems to prevent infiltration of surface water into the CCR as described in **Section 4.1.1**. The consolidated and capped areas will be subject to enhanced groundwater monitoring via MNA.

This alternative eliminates CCR sluicing/plant process water discharges and, with the consolidation of the CCR footprint and the installation of a cap, will reduce infiltration through the CCR. This is expected to address the major contributor to the observed GPS exceedances, which is exposure of CCR material to precipitation/surface water infiltration. Further leaching of metals and migration within groundwater will be reduced and may be eliminated over time. MNA is included with this alternative to monitor changes in groundwater impacts and the effectiveness of degradation mechanisms on groundwater concentrations over time.

5.4 ALTERNATIVE 4 – EXCAVATE AND DISPOSE ON SITE WITH MNA

Alternative 4 includes closing the OGS Ash Pond (no further discharge), excavation of CCR from the OGS Ash Pond, and creation of a new on-site disposal area with a liner and cap system. This alternative will serve to entomb the CCR from the OGS Ash Pond and allow for the collection and management of liquids generated from the disposal area. Further releases from the OGS Ash Pond will be prevented by the use of engineering controls constructed/installed to meet the design criteria for new CCR landfills required under 40 CFR 257.70.

This alternative eliminates CCR sluicing/plant process water discharges and, with the consolidation of the CCR footprint and the installation of a new on-site disposal area liner and cap, will reduce infiltration through the CCR. This is expected to address the major contributor to the observed GPS exceedances, which is exposure of CCR material to precipitation/surface water infiltration. MNA is included with this alternative to monitor changes in groundwater impacts and the effectiveness of degradation mechanisms on groundwater concentrations over time.

5.5 ALTERNATIVE 5 – EXCAVATE AND DISPOSE OFF SITE WITH MNA

Alternative 5 includes closing the OGS Ash Pond (no further discharge), excavation of all CCR from the OGS Ash Pond, and transport to an approved off-site landfill. Further on-site releases from the OGS Ash Pond will be prevented by removing the source material from the site, which eliminates the potential for ongoing leaching of constituents into groundwater at OGS.

This alternative eliminates CCR sluicing/plant process water discharges and, with the removal of CCR from the site, will eliminate infiltration through the CCR. This is expected to address the major contributor to the observed GPS exceedances, which is exposure of CCR material to precipitation/ surface water infiltration. MNA is included with this alternative to monitor changes in groundwater impacts and the effectiveness of degradation mechanisms on groundwater concentrations over time.

6.0 EVALUATION OF CORRECTIVE MEASURE ALTERNATIVES

As required by 40 CFR 257.96(c), the following sections provide an evaluation of the effectiveness of corrective measure alternatives in meeting the requirements and objectives outlined in 40 CFR 257.97. The evaluation addresses the requirements and objectives identified in 40 CFR 257.96(c)(1) through (3), which include:

- The performance, reliability, ease of implementation, and potential impacts of appropriate potential remedies, including safety impacts, cross-media impacts, and control of exposure to residual contamination;
- The time required to begin and complete the remedy; and

- The institutional requirements, such as state or local permit requirements or other environmental or public health requirements that may substantially affect implementation of the remedy.

In addition to the discussion of the items listed above, **Table 4** provides a summary of the initial evaluation of the alternatives including each of the criteria listed in 40 CFR 257.97.

6.1 ALTERNATIVE 1 – NO ACTION

As described in **Section 5.1**, the No Action alternative is only included as a baseline condition and a point of comparison for the other alternatives. This alternative does not satisfy all five criteria in 40 CFR 257.97(b)(1) through (5), so it is not an acceptable corrective measure under the CCR Rule. For comparison only, Alternative 1 is evaluated with regard to the criteria in 40 FR 257.96(c) below:

- **Performance, Reliability, Implementation, and Impacts.**
  - Performance – The ability to attain the GPS for cobalt without any additional action is unlikely.
  - Reliability – Alternative 1 does not provide any reduction in existing risk.
  - Implementation – Nothing is required to implement Alternative 1.
  - Impacts – No additional safety or cross-media impacts are expected with Alternative 1. This alternative does not control current suspected routes of exposure to residual contamination.

- **Timing.** No time is required to begin. However, the time required to attain the GPS for cobalt under Alternative 1 is unknown.

- **Institutional Requirements.** No institutional requirements beyond maintaining current regulatory approvals exist for Alternative 1.

6.2 ALTERNATIVE 2 – CLOSE AND CAP IN PLACE WITH MNA

As described in **Section 5.2**, Alternative 2 includes closing the OGS Ash Pond, covering the CCR materials with a cap, and establishing vegetation in accordance with the requirements for closure in place in 40 CFR 257.102(d).

- **Performance, Reliability, Implementation, and Impacts.**
  - Performance – Ceasing wastewater discharges and closing the impoundments by capping is expected to address infiltration, which is a key contributor to groundwater impacts. MNA monitoring will identify, if active, the natural attenuation processes that reduce mass, toxicity, mobility, volume, or concentrations of the constituents of concern in groundwater. Alternative 2 is capable of and expected to attain the GPS for cobalt.

  - Reliability – The expected reliability of capping is good. Capping is a common practice and standard remedial method for closure in place in remediation and solid waste management. There is significant industry experience with the design and construction of this method.

  - Implementation – The complexity of constructing the cap is low. Dewatering will be required to the extent a suitable subgrade is established for cap construction, which can likely be achieved through standard dewatering methods. The cap construction may put a high demand on the local supply of suitable cap materials. The local availability of cap materials will be evaluated further during remedy selection. The equipment and personnel required to implement Alternative 2 are not specialized and are generally readily available.

  – Impacts – Safety impacts associated with the implementation of Alternative 2 are not significantly different than other heavy civil construction projects. Cross-media impacts are expected to be limited due to the small volume of CCR expected to be relocated on site, the short duration of cap construction, the effectiveness of standard engineering controls during construction (e.g., dust control), and the lack of off-site transportation of CCR. The potential for exposure to residual contamination is low since CCR will be capped.

- **Timing.** Closure of the OGS Ash Pond can be completed within 1 to 2 years of remedy selection. At OGS, the closure of the OGS Ash Pond is expected to be completed by the end of 2022. The time required to attain the GPS for cobalt will be evaluated further during the remedy selection process, but is expected to take between 2 and 10 years after closure construction is complete. Alternative 2 can provide full protection within the 30-year post-closure monitoring period.

- **Institutional Requirements.** The following permits and approvals are expected to be required to implement Alternative 2:
  – IDNR Closure Permit
  – State and local erosion control/construction storm water management permits

6.3 ALTERNATIVE 3 – CONSOLIDATE ON SITE AND CAP WITH MNA

As described in **Section 5.3**, Alternative 3 includes closing the OGS Ash Pond, relocating and consolidating CCR into a smaller footprint within the CCR surface impoundments, covering the CCR materials with a cap, and establishing vegetation in accordance with the requirements for closure in place in 40 CFR 257.102(d).

- **Performance, Reliability, Implementation, and Impacts.**
  – Performance – Ceasing wastewater discharges and closing the impoundments by capping is expected to address infiltration, which is a key contributor to groundwater impacts. The consolidation of CCR into a smaller footprint may enhance the performance of the cap by further reducing the area exposed to limited post-construction infiltration through the cap. MNA monitoring will identify, if active, the natural attenuation processes that reduce mass, toxicity, mobility, volume, or concentrations of the constituents of concern in groundwater. Alternative 3 is capable of and expected to attain the GPS for cobalt.

  – Reliability – The expected reliability of capping is good. Capping is a common practice and standard remedial method for closure in place in remediation and solid waste management. There is significant industry experience with the design and construction of this method. A consolidated cap footprint may enhance reliability by reducing the scale of post-closure maintenance.

  – Implementation – The complexity of constructing the cap is low. The logistics of moving CCR around the site to consolidate the closure footprint increases the complexity of the alternative. CCR dewatering will be required to the extent required to excavate and relocate CCR within the CCR impoundments and provide a suitable subgrade for cap construction. Some conditioning (e.g., drying) of relocated CCR is expected during on-site re-disposal. Alternative 3 can likely be achieved through standard dewatering and conditioning methods. Although the cap footprint will be minimized, cap construction may put a high demand on the local supply of suitable cap materials. The local availability of cap materials will be evaluated further during remedy selection. The equipment and personnel required to implement Alternative 3 are not specialized and are generally readily available.

- Impacts – Safety impacts associated with the implementation of Alternative 3 are not significantly different than other heavy civil construction projects. The level of disturbance required to consolidate CCR before capping may represent some increase in safety risk due to site conditions and on-site construction traffic. Cross-media impacts are expected to be limited due to the small volume of CCR expected to be relocated on site, the short duration of cap construction, the effectiveness of standard engineering controls during construction (e.g., dust control), and the lack of off-site transportation of CCR. The potential for exposure to residual contamination is low since CCR will be capped and the footprint of the cap minimized.

- **Timing.** Closure of the OGS Ash Pond can be completed within 1 to 2 years of remedy selection. At OGS, the closure of the OGS Ash Pond is expected to be completed by the end of 2022. The time required to attain the GPS for cobalt will be evaluated further during the remedy selection process, but is expected to take between 2 and 10 years after closure construction is complete. The level of source disturbance during construction may increase the time required to reach GPS. The consolidation of CCR into a smaller cap area may decrease the time to reach GPS. Alternative 3 can provide full protection within the 30-year post-closure monitoring period.

- **Institutional Requirements.** The following permits and approvals are expected to be required to implement Alternative 3:
  - IDNR Closure Permit
  - State and local erosion control/construction storm water management permits

6.4 ALTERNATIVE 4 – EXCAVATE AND DISPOSE ON SITE WITH MNA

As described in **Section 5.4**, Alternative 4 includes closing the OGS Ash Pond, excavation of CCR from the source area, and creation of a new on-site disposal that meets the design criteria for new CCR landfills required under 40 CFR 257.70

- **Performance, Reliability, Implementation, and Impacts.**
  - Performance – Ceasing wastewater discharges and closing the OGS Ash Pond by removing and re-disposing CCR in a new lined/capped disposal area is expected to address infiltration, which is a key contributor to groundwater impacts. The consolidation of CCR into a smaller footprint may enhance the performance of the cap by further reducing the area exposed to limited post-construction infiltration through the cap. The separation from groundwater and other location criteria for the new on-site disposal facility may enhance the performance of this alternative. MNA monitoring will identify, if active, the natural attenuation processes that reduce mass, toxicity, mobility, volume, or concentrations of the constituents of concern in groundwater. Alternative 4 is capable of and expected to attain the GPS for cobalt.

- Reliability – The expected reliability of on-site re-disposal with a composite liner and cap is good. Disposal facilities that meet the requirements in 40 CFR 257.70 or other similar requirements have been used for solid waste disposal including municipal and industrial waste for numerous years. There is significant industry experience with the design and construction of similar disposal facilities. The composite liner and cover, combined with a consolidated disposal footprint, may enhance reliability by reducing infiltration and the scale of post-closure maintenance. At the same time, post-closure maintenance is likely more complex due to maintenance of a leachate collection system and geosynthetic repairs requiring specialized personnel, material, and equipment.

- Implementation – The complexity of constructing the new liner and cap is moderate due to the composite design. The limited area available at the facility for developing an on-site disposal facility makes this alternative logistically complex. Significant volumes of CCR will be excavated and stored on site while the disposal facility is constructed. Significant dewatering will be required to excavate and relocate CCR to a temporary storage area. Conditioning (e.g., drying) of relocated CCR is expected to facilitate temporary storage and on-site re-disposal. Alternative 4 can likely be achieved through standard dewatering and conditioning methods, but may be impacted by the space available for these activities. Although the post-closure CCR footprint will be minimized, composite liner and cap construction may put a high demand on the local supply of suitable cap materials. The local availability of liner and cap materials will be evaluated further during remedy selection. The equipment and personnel required to implement Alternative 4 are not specialized and are generally readily available, with the exception of the resources needed to install the geosynthetic portions of the composite liner and cover, which are not locally available.

- Impacts – Safety impacts associated with the implementation of Alternative 4 are not significantly different than other heavy civil construction projects. However, the level of disturbance required to excavate, store, and re-dispose CCR on site and the traffic required to import composite liner and cap material are not typical and likely represent an increase in safety risk due to site conditions, on-site construction traffic, and incoming/outgoing off-site construction traffic. A risk of cross-media impacts is possible due to the large volume of CCR to be excavated, stored, and relocated on site. The potential for exposure to residual contamination is low since CCR will be capped and the footprint of the cap minimized.

- **Timing.** Closure of the OGS Ash Pond can be completed within 1 to 2 years of remedy selection. At OGS, the closure of the OGS Ash Pond is expected to be completed by the end of 2022. However, the time required to permit and develop the on-site disposal facility may extend this schedule. The time required to attain the GPS for cobalt will be evaluated further during the remedy selection process, but is expected to take between 2 and 10 years after closure construction is complete. The level of source disturbance during construction may increase the time required to reach GPS. The consolidation of CCR into a new on-site disposal facility with a composite liner and cap may decrease the time to reach GPS. Alternative 4 can provide full protection within the 30-year post-closure monitoring period.

- **Institutional Requirements.** The following permits and approvals are expected to be required to implement Alternative 4:

- IDNR Closure Permit
- IDNR Disposal Facility (Landfill) Permit
- State and local erosion control/construction storm water management permits

6.5 ALTERNATIVE 5 – EXCAVATE AND DISPOSE OFF SITE WITH MNA

As described in **Section 5.5**, Alternative 5 includes closing the OGS Ash Pond, excavation of CCR from the source area, and transporting the CCR off site for disposal.

- **Performance, Reliability, Implementation, and Impacts.**
  - Performance – Ceasing wastewater discharges and closing the OGS Ash Pond by removing and re-disposing CCR off site will eliminate the source material exposed to infiltration, which is a key contributor to groundwater impacts. The off-site disposal of CCR prevents further releases at OGS, but introduces the possibility of releases at the receiving facility. MNA monitoring will identify, if active, the natural attenuation processes that reduce mass, toxicity, mobility, volume, or concentrations of the constituents of concern in groundwater. Alternative 5 is capable of and expected to attain the GPS for cobalt.

  - Reliability – The expected reliability of excavation and off-site disposal is good. Off-site disposal facilities are required to meet the requirements in 40 CFR 257.70 or other similar requirements, which have been used for solid waste disposal including municipal and industrial waste for numerous years. There is significant industry experience with the design and construction of these disposal facilities.

  - Implementation – The complexity of excavating CCR for off-site disposal is low. The scale of CCR excavation (expected to exceed 450,000 cy), off-site transportation, and the permitting/development of off-site disposal facility airspace makes this alternative logistically complex. Significant dewatering will be required to excavate CCR. Conditioning (e.g., drying) of excavated CCR is expected to facilitate off-site transportation and re-disposal. Alternative 5 can likely be achieved through standard dewatering and conditioning methods, but may be impacted by the space available for these activities. Although the source area at OGS is eliminated, the development of off-site disposal airspace will put a high demand on the receiving disposal facility, which may not have the current physical or logistical capacity to receive large volumes of CCR in a short period of time. The equipment and personnel required to implement on-site and off-site aspects of Alternative 5 are not specialized and are generally readily available, with the exception of the resources needed to install the geosynthetic portions of the off-site composite liner and cover, which are not locally available.

  - Impacts – Safety impacts associated with the implementation of Alternative 5 are not significantly different than other heavy civil construction projects. However, the level of disturbance required to excavate, transport, and re-dispose CCR and the traffic required to import composite liner and cap material at the receiving disposal facility are not typical and likely represent an increase in safety risk due to large volumes of incoming/outgoing off-site construction traffic at both sites. A risk of cross-media impacts is possible due to the large volume of CCR to be excavated and transported from the site. The potential for exposure to residual contamination on site is very low since CCR will be removed; however, the off-site potential for exposure to CCR is increased due to the relocation of the source material.

- **Timing.** Closure of the OGS Ash Pond can be completed within 1 to 2 years of remedy selection. At OGS, the closure of the OGS Ash Pond is expected to be completed by the end of 2022. However, the time required to secure the off-site disposal airspace required to complete this alternative, including potential procurement, permitting, and construction, may extend this schedule significantly. The time required to attain the GPS for cobalt will be evaluated further during the remedy selection process, but is expected to take between 2 and 10 years after closure construction is complete. The level of source disturbance during construction may increase the time required to reach GPS. The removal of CCR from OGS may decrease the time to reach GPS. Alternative 5 can provide full protection within the 30-year post-closure monitoring period.

- **Institutional Requirements.** The following permits and approvals are expected to be required to implement Alternative 5:
  - IDNR Closure Permit
  - Depending on the off-site disposal facility, approval of off-site disposal facility owner or landfill permit for new off-site facility
  - State and local erosion control/construction storm water management permits
  - Transportation agreements and permits (local roads and railroads)

  Depending on the off-site disposal facility, state solid waste comprehensive planning approvals may also be required.

7.0 SUMMARY OF ASSESSMENT

An initial qualitative assessment of the advantages and disadvantages of each Corrective Measure Alternative presented in **Section 4.0** is provided in **Table 4**. Each of the identified Corrective Measure Alternatives exhibits both favorable and unfavorable outcomes with respect to the assessment criteria. In accordance with 40 CFR 257.97(c), the facility must consider all of the evaluation factors and select a remedy that meets the standards of 257.97(b) as soon as feasible.

We continue to advance additional data collection efforts to identify the appropriate corrective action measure for the Site. We will continue to update **Table 4** and develop a quantitative scoring matrix to identify a preferred corrective action.

8.0 REFERENCES

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Tables

Table 1. Water Level Summary
IPL - Ottumwa Generating Station / SCS Engineers Project #25218202.00

Ground Water Elevation in feet above mean sea level (amsl)									
Well Number	**MW-301**	**MW-302**	**MW-303**	**MW-304**	**MW-305**	**MW-306**	**MW-307**	**MW-308**	**MW-309**
Top of Casing Elevation (feet amsl)	686.63	673.90	661.07	682.84	683.91	683.47	657.56	655.39	654.94
Screen Length (ft)	10.00	5.00	5.00	5.00	5.00	5.00	5	5	5
Total Depth (ft from top of casing)	17.0	25.8	17.5	52.3	51.5	36.6	28	25	27.5
Top of Well Screen Elevation (ft)	567.40	563.24	579.60	577.48	577.48	577.48	633.08	633.87	630.95
Measurement Date									
April 26, 2016	682.80	655.63	652.42	655.37	661.67	670.86			
June 23, 2016	682.58	655.65	652.89	656.53	662.36	670.64			
August 9, 2016	682.27	655.52	651.76	653.79	660.78	670.35			
October 26-27, 2016	682.04	655.67	652.17	655.03	661.37	670.21			
January 18-19, 2017	681.67	655.46	651.74	654.50	660.87	669.89	648.81	647.42	646.66
April 19-20, 2017	682.15	656.35	654.57	657.48	663.27	670.69	653.62	651.09	650.16
June 20-21, 2017	681.91	655.65	652.42	654.75	661.26	669.94	649.85	648.26	647.60
August 21-23, 2017	681.28	655.13	650.58	652.39	659.00	668.77	645.78	643.12	641.82
November 8, 2017	681.54	655.40	651.34	653.03	659.76	669.04	647.37	644.99	644.20
April 18, 2018	681.53	655.71	652.47	655.55	660.99	668.92	649.66	647.91	647.65
May 30, 2018	NM	NM	NM	NM	NM	NM	652.45	651.05	650.98
June 28, 2018	NM	NM	NM	NM	NM	NM	652.87	651.43	651.47
July 18, 2018	NM	NM	NM	NM	NM	NM	652.27	650.67	650.69
August 14-15, 2018	680.91	656.05	652.57	656.35	661.56	668.66	NM	NM	NM
August 29, 2018	681.09	655.89	655.07	657.82	NM	NM	NM	NM	NM
October 16, 2018	682.50	656.91	656.17	658.20	663.37	670.24	654.13	NM	651.61
January 8, 2019	682.22	656.03	654.65	656.28	662.13	669.84	NM	NM	NM
April 8, 2019	682.69	657.23	655.55	659.33	664.01	670.96	654.90	653.70	653.55
Bottom of Well Elevation (ft)	669.63	648.10	643.57	630.54	632.41	646.87	629.56	630.39	627.44

Notes:
NM = not measured

Created by: KAK Date: 5/1/2017
Last rev. by: JR Date: 4/12/2019
Checked by: MDB Date: 4/12/2019

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Table 2. CCR Rule Groundwater Samples Summary
Ottumwa Generating Station / SCS Engineers Project #25218202.00

Sample Dates	Downgradient Wells					Background Well
	MW-302	MW-303	MW-304	MW-305	MW-306	MW-301
4/26/2016	B	B	B	B	B	B
6/23/2016	B	B	B	B	B	B
8/10-11/2016	B	B	B	B	B	B
10/26-27/2016	B	B	B	B	B	B
1/18/2017	B	B	B	B	B	B
4/19/2017	B	B	B	B	B	B
6/20-21/2017	B	B	B	B	B	B
8/22-23/2017	B	B	B	B	B	B
11/8/2017	D	D	D	D	D	D
4/18/2018	A	A	A	A	A	A
8/14-15/2018	A	A	A	A	A	A
8/29/2018	A-R	A-R	A-R	--	--	A-R
10/16/2018	A	A	A	A	A	A
1/8/2019	A-R	A-R	A-R	A-R	A-R	A-R
4/8/2019	A	A	A	A	A	A

Abbreviations:
B = Background Sample Event
D = Detection Monitoring Sampling Event
-- = Not Applicable
A = Assessment Monitoring Sampling Event
A-R = Assessment Monitoring Resampling Event

Created by: NDK Date: 1/8/2018
Last revision by: MDB Date: 8/8/2019
Checked by: NDK Date: 8/8/2019

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Table 3. Groundwater Analytical Results Summary - CCR Program - Detection Monitoring
Ottumwa Generating Station Ash Pond / SCS Engineers Project #25218202.00

Parameter Name	UPL Method	UPL	GPS	Background Well MW-301 4/18/2018	MW-301 8/14/2018, 8/29/2018 ^	MW-301 10/16/2018, 1/8/2019 ^^	MW-301 1/8/2019^^	MW-301 4/8/2019
Appendix III								
Boron, ug/L	P	820		480	735	410	NA	375
Calcium, mg/L	P	78.7		63.0	72.5	47.2	NA	43.5
Chloride, mg/L	P	86.8		63.4	63.1	33.9	NA	50.2
Fluoride, mg/L	P	0.484		0.22	0.27	0.3	NA	<0.500
Field pH, Std. Units	P	6.87		6.41	6.26	6.27	5.68	6.61
Sulfate, mg/L	P	199		186	181	164	NA	80.8
Total Dissolved Solids, mg/L	P	628		514	532	392	NA	340
Appendix IV		UPL	GPS					
Antimony, ug/L	P*	0.22	6	<0.026	0.20 J	<0.078	NA	<1.00
Arsenic, ug/L	P*	0.53	10	0.074 J	0.29 J	0.16 J	NA	<2.00
Barium, ug/L	P	68.8	2,000	31.6	44.5	28.1	NA	25.5
Beryllium, ug/L	DQ	DQ	4	<0.012	0.14 J	<0.089	NA	<1.00
Cadmium, ug/L	NP*	0.12	5	0.023 J	0.16 J	<0.033	NA	<0.500
Chromium, ug/L	P	1.07	100	<0.054	0.25 J	0.11 J,B	NA	<5.00
Cobalt, ug/L	NP	4.1	6	0.46 J	1.4	0.36 J,B		<0.500
Fluoride, mg/L	P	0.48	4	0.22	0.27	0.3	NA	<0.500
Lead, ug/L	NP*	0.10	15	0.041 J	0.18 J	<0.13	NA	<0.500
Lithium, ug/L	P	34.2	40	19.1	26.5	19.4	NA	15.5
Mercury, ug/L	DQ	DQ	2	<0.090	<0.083	<0.090	NA^^	<0.200
Molybdenum, ug/L	P	1.74	100	0.67 J	1.3	0.72 J	NA	<2.00
Selenium, ug/L	P	8.55	50	4.3	6.3	3.4	NA	<5.00
Thallium, ug/L	NP*	0.14	2	<0.036	0.16 J	<0.099	NA	<1.00
Radium 226/228 Combined, pCi/L	P	2.15	5	0.513	1.19	1.7	NA	0.0956

Parameter Name	Compliance Wells MW-302 11/8/2017	MW-302 4/18/2018	MW-302 8/14/2018, 8/29/2018 ^	MW-302 10/16/2018, 1/8/2019 ^^	MW-302 1/8/2019^^	MW-302 4/8/2019	MW-303 11/8/2017	MW-303 4/18/2018	MW-303 8/14/2018, 8/29/2018 ^	MW-303 10/16/2018, 1/8/2019 ^^	MW-303 1/8/2019^^	MW-303 4/8/2019
Appendix III												
Boron, ug/L	1,320	1,200	1,240	1,100	NA	1,340	1,070	987	1,010	549	NA	286
Calcium, mg/L	183	177	185	146	NA	199	234	212	213	195	NA	172
Chloride, mg/L	254	246	259	214	NA	240	185	198	64.8	57	NA	22.1
Fluoride, mg/L	0.20 J	0.26	0.26	0.24	NA	<0.500	0.19 J	0.22	0.31	0.24	NA	<0.500
Field pH, Std. Units	6.55	6.47	6.76	6.37	6.58	6.61	6.60	6.63	6.83	6.66	6.83	7.00
Sulfate, mg/L	786	899	847	785	NA	840	348	328	164	389	NA	261
Total Dissolved Solids, mg/L	1,620	1,690	1,840	1,400	NA	1,640	1,290	1,300	832	1,150	NA	886
Appendix IV												
Antimony, ug/L	NA	<0.026	<0.15	0.26 J,B	NA	<1.00	NA	0.098 J	0.16 J	0.2 J,B	NA	<1.00
Arsenic, ug/L	NA	0.16 J	0.30 J	1.9	NA	<2.00	NA	0.43 J	0.60 J	0.55 J	NA	<2.00
Barium, ug/L	NA	17.7	18.3	28.9	NA	19.2	NA	69.5	77.3	95.2	NA	54.1
Beryllium, ug/L	NA	<0.012	<0.12	0.22 J	NA	<1.00	NA	0.017 J	<0.12	<0.089	NA	<1.00
Cadmium, ug/L	NA	0.22 J	0.21 J	0.67	NA	<0.500	NA	0.44 J	0.36 J	0.24 J	NA	<0.500
Chromium, ug/L	NA	0.46 J	0.48 J	1.6	NA	<5.00	NA	0.12 J	0.19 J	0.15 J,B	NA	<5.00
Cobalt, ug/L	NA	0.90 J	1.50	4.0		1.2	NA	2.1	2.2	1.7 B		<0.500
Fluoride, mg/L	NA	0.26	0.26	0.24	NA	<0.500	NA	0.22	0.31	0.24	NA	<0.500
Lead, ug/L	NA	0.098 J	0.12 J	3.9	NA	<0.500	NA	0.069 J	0.13 J	<0.13	NA	<0.500
Lithium, ug/L	NA	7.5 J	6.9 J	8.6 J	NA	10.4	NA	<4.6	6.9 J	<4.6	NA	<10.0
Mercury, ug/L	NA	0.096 J	<0.083	NA^^	<0.090	<0.200	NA	<0.090	<0.083	NA^^	<0.090	<0.200
Molybdenum, ug/L	NA	0.59 J	0.54 J	<0.57	NA	<2.00	NA	0.61 J	0.98 J	5.5	NA	7.46
Selenium, ug/L	NA	<0.086	<0.16	0.84 J,B	NA	<5.00	NA	0.23 J	0.35 J	0.37 J,B	NA	<5.00
Thallium, ug/L	NA	<0.036	<0.14	0.16 J	NA	<1.00	NA	<0.036	<0.14	<0.099	NA	<1.00
Radium 226/228 Combined, pCi/L	NA	0.746	1.12	1.7	NA	0.116	NA	0.529	1.82	1.68	NA	0.391

Parameter Name	MW-304 11/8/2017	MW-304 4/18/2018	MW-304 8/14/2018, 8/29/2018 ^	MW-304 10/16/2018, 1/8/2019 ^^	MW-304 1/8/2019^^	MW-304 4/8/2019	MW-305 11/8/2017	MW-305 4/18/2018	MW-305 8/15/2018	MW-305 10/16/2018	MW-305 1/8/2019^^	MW-305 4/8/2019	MW-306 11/8/2017	MW-306 4/18/2018	MW-306 8/15/2018	MW-306 10/16/2018	MW-306 1/8/2019^^	MW-306 4/8/2019
Appendix III																		
Boron, ug/L	1,040	991	1,000	930	NA	1,110	925	886	911	835	NA	1,040	881	919	915	862	NA	1,070
Calcium, mg/L	136	131	138	123	NA	131	99.5	97.6	102.0	96.2	NA	114	73.1	74.1	78.9	80.0	NA	95.4
Chloride, mg/L	417	400	375	410	NA	325	282	289	265	281	NA	248	50.4	54.4	58.2	83.3	NA	97.6
Fluoride, mg/L	0.96	0.92	1.00	1.0	NA	1.28	0.40	0.40	0.44	0.40	NA	0.748	0.11 J	0.11 J	0.13 J	<0.19	NA	<0.500
Field pH, Std. Units	7.00	6.9	7.34	6.86	7.16	7.17	7.01	6.9	7.21	6.86	6.99	7.06	6.49	6.42	6.74	6.42	6.65	6.66
Sulfate, mg/L	194	198	185	184	NA	182	138	147	139	129	NA	108	274	289	275	285	NA	272
Total Dissolved Solids, mg/L	1,270	1,300	3,680	1,180	NA	1,140	1,040	1,070	1,060	1,070	NA	1,010	773	805	840	884	NA	930
Appendix IV																		
Antimony, ug/L	NA	<0.026	0.19 J	<0.078	NA	<1.00	NA	0.089 J	<0.15	0.096 J,B	NA	<1.00	NA	0.094 J	<0.15	0.10 J,B	NA	<1.00
Arsenic, ug/L	NA	0.68 J	1.3	0.96 J	NA	<2.00	NA	0.51 J	0.72 J	0.66 J	NA	<2.00	NA	0.38 J	0.65 J	0.60 J	NA	<2.00
Barium, ug/L	NA	88.5	87.4	91	NA	80.5	NA	116	118	125	NA	119	NA	48.2	51.6	56.0	NA	58.4
Beryllium, ug/L	NA	0.026 J	0.21 J	<0.089	NA	<1.00	NA	<0.012	<0.12	<0.089	NA	<1.00	NA	<0.012	<0.12	<0.089	NA	<1.00
Cadmium, ug/L	NA	<0.018	0.17 J	0.07 J	NA	<0.500	NA	0.054 J	0.086 J	0.044 J	NA	<0.500	NA	0.88	0.76	0.96	NA	1.08
Chromium, ug/L	NA	2.0	5.9	1.4	NA	<5.00	NA	0.26 J	0.41 J	0.3 J,B	NA	<5.00	NA	0.37 J	0.70 J	0.46 J,B	NA	<5.00
Cobalt, ug/L	NA	0.39 J	0.92 J	0.45 J,B		<0.500	NA	**14.5**	**15.6**	**17.2**	**16.4**	**17**	NA	4.8	5.5	**6.4**	**6.2**	**6.92**
Fluoride, mg/L	NA	0.92	1.00	1.0	NA	1.28	NA	0.40	0.44	0.40	NA	0.748	NA	0.11 J	0.13 J	<0.19	NA	<0.500
Lead, ug/L	NA	0.37 J	0.81 J	0.66 J	NA	<0.500	NA	0.12 J	0.31 J	<0.13	NA	<0.500	NA	0.040 J	0.20 J	<0.13	NA	<0.500
Lithium, ug/L	NA	<4.6	<4.6	<4.6	NA	<10.0	NA	<4.6	<4.6	<4.6	NA	<10.0	NA	<4.6	<4.6	<4.6	NA	<10.0
Mercury, ug/L	NA	<0.090	<0.083	NA^^	<0.090	<0.200	NA	<0.090	<0.090	NA^^	<0.090	<0.200	NA	<0.090	<0.083	NA^^	<0.090	<0.200
Molybdenum, ug/L	NA	2.0	2.4	1.9	NA	<2.00	NA	7.1	6.5	7.3	NA	7.17	NA	5.7	4.7	5.1	NA	4.32
Selenium, ug/L	NA	<0.086	0.50 J	0.26 J,B	NA	<5.00	NA	0.12 J	0.36 J	0.33 J,B	NA	<5.00	NA	<0.086	0.21 J	0.22 J,B	NA	<5.00
Thallium, ug/L	NA	<0.036	0.15 J	<0.099	NA	<1.00	NA	0.32 J	0.33 J	0.33 J	NA	<1.00	NA	0.083 J	<0.14	0.12 J	NA	<1.00
Radium 226/228 Combined, pCi/L	NA	2.08	3.74	1.25	NA	2.42	NA	0.676	1.33	1.32	NA	0.685	NA	0.305	0.985	1.34	NA	0.155

4.4 Italics and blue shaded cell indicates the compliance well result exceeds the UPL (background) and the Limit of Quantitation (LOQ).

30.8 Bold and yellow highlighted cell indicates the compliance well result exceeds the GPS.

Abbreviations:
UPL = Upper Prediction Limit
NA = Not Analyzed
P = Parametric UPL with 1-of-2 retesting
GPS = Groundwater Protection Standard
DQ = Double Quantification Rule (not detected in background)
NP = Nonparametric UPL (highest background value)
LOD = Limit of Detection
LOQ = Limit of Quantitation
J = Estimated concentration at or above the LOD and below the LOQ.
B = Analyte was detected in the associated Method Blank.

* = UPL is below the LOQ for background sampling. For compliance wells, only results confirmed above the LOQ are evaluated as potential SSIs above background.
^ = During the August 2018 sampling event, samples for chloride, fluoride, sulfate, and total dissolved solids at MW-301, MW-302, MW-303, and MW-304 were received by the lab above the required temperature. The wells were resampled for these parameters on 8/29/2018.
^^ = During the October 2018 sampling event, samples were not analyzed for mercury due a laboratory error. The wells were resampled for mercury on 1/8/2019. The 1/8/2019 samples from MW-305 and MW-306 were also analyzed for cobalt.

Notes:
1. An individual result above the UPL or GPS does not constitute a statistically significant increase (SSI) above background or statistically significant level above the GPS. See the accompanying letter text for identification of statistically significant results.
2. GPS is the United States Environmental Protection Agency (US EPA) Maximum Contamination Level (MCL), if established; otherwise, the values are from 40 CFR 257.95(h)(2).
3. Interwell UPLs calculated based on results from background well MW-301.

Created by: NDK Date: 5/1/2018
Last revision by: MDB Date: 7/31/2019
Checked by: NDK Date: 7/31/2019

I:\25218202.00\Deliverables\OGS ACM\Tables\[3_CCR GW Screening Summary_OGS.xlsx]Table

Table 4. Preliminary Evaluation of Corrective Measure Alternatives
Ottumwa Generating Station / SCS Engineers Project #25218202.00

	Alternative #1 No Action	Alternative #2 Close and Cap in place with MNA	Alternative #3 Consolidate on Site and Cap with MNA	Alternative #4 Excavate and Dispose on site with MNA	Alternative #5 Excavate and Dispose in Off-Site Landfill
CORRECTIVE ACTION ASSESSMENT - 40 CFR 257.97(b)					
257.97(b)(1) Is remedy protective of human health and the environment?	No	Yes	Yes	Yes	Yes
257.97(b)(2) Can the remedy attain the groundwater protection standard?	Unlikely	Yes	Yes	Yes	Yes
257.97(b)(3) Can the remedy control the source(s) of releases so as to reduce or eliminate, to the maximum extent feasible, further releases of constituents in appendix IV to this part into the environment?	No	Yes	Yes	Yes	Yes
257.97(b)(4) Can the remedy remove from the environment as much of the contaminated material that was released from the CCR unit as is feasible?	Not Applicable - No release of CCR	Not Applicable - No release of CCR	Not Applicable - No release of CCR	Not Applicable - No release of CCR	Not Applicable - No release of CCR
257.97(b)(5) Can the remedy comply with standards for management of wastes as specified in §257.98(d)?	Not Applicable	Yes	Yes	Yes	Yes
LONG- AND SHORT-TERM EFFECTIVENESS - 40 CFR 257.97(c)(1)					
257.97(c)(1)(i) Magnitude of reduction of existing risks	No reduction of existing risk	Existing risk reduced by achieving GPS	Same as Alternative #2	Same as Alternative #2	Same as Alternative #2
257.97(c)(1)(ii) Magnitude of residual risks in terms of likelihood of further releases due to CCR remaining following implementation of a remedy	No reduction of existing risk. Residual risk is limited for all alternatives due to limited extent of impacts and lack of receptors.	Magnitude of residual risk of further releases is lower than current conditions due to final cover eliminating infiltration through CCR; Residual risk is limited for all alternatives due to limited extent of impacts and lack of receptors	Same as Alternative #2 with potential further reduction in release risk due to CCR material footprint; However, limited to no overall risk reduction is provided due to lack of current/anticipated future receptors for groundwater impacts	Same as Alternative #3 with potential further reduction in release risk due to composite liner and cover; However, limited to no overall risk reduction is provided due to lack of current/anticipated future receptors for groundwater impacts	Same as Alternative #3 with potential further reduction in release risk due to removal of CCR from site; However, limited to no overall risk reduction is provided due to lack of current/anticipated future receptors for groundwater impacts
257.97(c)(1)(iii) The type and degree of long-term management required, including monitoring, operation, and maintenance	Not Applicable	30-year post-closure groundwater monitoring; Groundwater monitoring network maintenance and as-needed repair/replacement Final cover maintenance (e.g., mowing and as-needed repair); Periodic final cover inspections; Additional corrective action as required based on post-closure groundwater monitoring	Same as Alternative #2	Same as Alternative #2	No on-site long-term management required; Limited on-site post-closure groundwater monitoring until GPS are achieved; Receiving disposal facility will have same/similar long-term monitoring, operation, and maintenance requirements as Alternative #2

Table 4. Preliminary Evaluation of Corrective Measure Alternatives
Ottumwa Generating Station / SCS Engineers Project #25218202.00

	Alternative #1 No Action	Alternative #2 Close and Cap in place with MNA	Alternative #3 Consolidate on Site and Cap with MNA	Alternative #4 Excavate and Dispose on site with MNA	Alternative #5 Excavate and Dispose in Off-Site Landfill
LONG- AND SHORT-TERM EFFECTIVENESS - 40 CFR 257.97(c)(1) (continued)					
257.97(c)(1)(iv) Short-term risks - Implementation					
Excavation	None	Limited risk to community and environment due to limited amount of excavation (likely <100K cy) required to establish final cover subgrades and no off-site excavation	Same as Alternative #2 with increased risk to environment due to increased excavation volumes required for consolidation (likely >100K cy but <463K cy)	Same as Alternative #3 with increased risk to environment due to increased excavation volumes (~463K cy) and temporary CCR storage during disposal site construction required for removal and on-site re-disposal	Same as Alternative #4 with reduced risk to environment from excavation due to limited on-site storage
Transportation	None	No risk to community or environment from off-site CCR transportation; Typical risk due to construction traffic delivering final cover materials to site	Same as Alternative #2 with reduced risk from construction traffic due to reduced final cover material requirements (smaller cap footprint)	Same as Alternative #2 with increased risk from construction traffic due to increased material import requirements (liner and cap construction required)	Highest level of community and environmental risk due to CCR volume export (~463K cy)
Re-Disposal	None	Limited risk to community and environment due to limited volume of CCR re-disposal (likely <100K cy)	Same as Alternative #2 with increased risk to environment due to increased excavation volumes (likely >100K cy but <463K cy) required for consolidation	Same as Alternative #3 with increased risk to environment due to increased excavation volumes (~463K cy) and temporary CCR storage during disposal site construction required for removal and on-site re-disposal	Same as Alternative #4 with increased risk to community and environment due to re-disposal of large CCR volume (~463K cy) at another facility; Re-disposal risks are managed by the receiving disposal facility
257.97(c)(1)(v) Time until full protection is achieved	Unknown	To be evaluated further during remedy selection. Closure and capping anticipated by end of 2022. Groundwater protection timeframe to reach GPS potentially 2 to 10 years following closure construction, achievable within 30-year post-closure monitoring period.	Similar to Alternative #2. Potential for increase in time to reach GPS due to significant source disturbance during construction. Potential for decrease in time to reach GPS due to consolidation of CCR.	Similar to Alternative #2. Potential for increase in time to reach GPS due to significant source disturbance during construction. Potential decrease in time to reach GPS due to source isolation within liner/cover system.	Similar to Alternative #2. Potential for increase in time to reach GPS due to significant source disturbance during construction. Potential decrease in time to reach GPS due to impounded CCR source removal.
257.97(c)(1)(vi) Potential for exposure of humans and environmental receptors to remaining wastes, considering the potential threat to human health and the environment associated with excavation, transportation, re-disposal, or containment	No change in potential exposure	Potential for exposure is low. Remaining waste is capped.	Same as Alternative #2	Same as Alternative #2	No potential for on-site exposure to remaining waste since no waste remains on site; Risk of potential exposure is transferred to receiving disposal facility and is likely similar to Alternative #2
257.97(c)(1)(vii) Long-term reliability of the engineering and institutional controls	Not Applicable	Long-term reliability of cap is good; Significant industry experience with methods/controls; Capping is common practice/industry standard for closure in place for remediation and solid waste management	Same as Alternative #2 with potentially increased reliability due to smaller footprint and reduced maintenance	Same as Alternative #3	Success of remedy at OGS does not rely on long-term reliability of engineering or institutional controls; Overall success relies on reliability of the engineering and institutional controls at the receiving facility
257.97(c)(1)(viii) Potential need for replacement of the remedy	Not Applicable	Limited potential for remedy replacement if maintained; Some potential for remedy enhancement due to residual groundwater impacts following source control	Same as Alternative #2 with reduced potential need for remedy enhancement with consolidated/smaller closure area footprint	Same as Alternative #2 with further reduction in potential need for remedy enhancement composite with liner	No potential for remedy replacement; Limited potential for remedy enhancement due to residual groundwater impacts following source control

Table 4. Preliminary Evaluation of Corrective Measure Alternatives
Ottumwa Generating Station / SCS Engineers Project #25218202.00

	Alternative #1 No Action	Alternative #2 Close and Cap in place with MNA	Alternative #3 Consolidate on Site and Cap with MNA	Alternative #4 Excavate and Dispose on site with MNA	Alternative #5 Excavate and Dispose in Off-Site Landfill
SOURCE CONTROL TO MITIGATE FUTURE RELEASES - 40 CFR 257.97(c)(2)					
257.97(c)(2)(i) The extent to which containment practices will reduce further releases	No reduction in further releases	Cap will reduce further releases by minimizing infiltration through CCR	Same as Alternative #2 with further reduction due to consolidated/smaller closure footprint	Same as Alternative #3 with further reduction due to composite liner and 5-foot groundwater separation required by CCR Rule	Removal of CCR prevents further releases at OGS; Receiving disposal site risk similar to Alternative #3
257.97(c)(2)(ii) The extent to which treatment technologies may be used	Alternative does not rely on treatment technologies	Alternative does not rely on treatment technologies	Alternative does not rely on treatment technologies	Alternative does not rely on treatment technologies	Alternative does not rely on treatment technologies
IMPLEMENTATION - 40 CFR 257.97(c)(3)					
257.97(c)(3)(i) Degree of difficulty associated with constructing the technology	Not Applicable	Low complexity construction; Potentially lowest level of dewatering effort - dewatering required for cap installation only	Low complexity construction; Moderate degree of logistical complexity; Moderate level of dewatering effort - dewatering required for material excavation/placement and capping	Moderately complex construction due to composite liner and cover; High degree of logistical complexity due to excavation and on-site storage of ~463K cy of CCR while new lined disposal area is constructed; High level of dewatering effort - dewatering required for excavation of full CCR volume	Low complexity construction; High degree of logistical complexity including the excavation and off-site transport of ~463K cy of CCR and permitting/development of off-site disposal facility airspace; High level of dewatering effort - dewatering required for excavation of full CCR volume
257.97(c)(3)(ii) Expected operational reliability of the technologies	Not Applicable	High reliability based on historic use of capping as corrective measure	Same as Alternative #2	Same as Alternative #2	Success at OGS does not rely on operational reliability of technologies; Overall success relies on off-site disposal facility, which is likely same/similar to Alternative #2
257.97(c)(3)(iii) Need to coordinate with and obtain necessary approvals and permits from other agencies	Not Applicable	Need is low in comparison to other alternatives; State Closure Permit required	Same as Alternative #2	Need is high in comparison to other alternatives State Closure Permit required; State Landfill Permit may be required	Need is highest in comparison to other alternatives; State Closure Permit required; Approval of off-site disposal site owner required; May require State solid waste comprehensive planning approval; Local road use permits likely required
257.97(c)(3)(iv) Availability of necessary equipment and specialists	Not Applicable	Necessary equipment and specialists are highly available; Highest level of demand for cap construction material	Same as Alternative #2; Lowest level of demand for cap construction material	Same as Alternative #2; Moderate level of demand for liner and cap construction material	Availability of necessary equipment to develop necessary off-site disposal facility airspace and transport ~463K cy of CCR to new disposal facility will be a limiting factor in the schedule for executing this alternative; No liner or cover material demands for on-site implementation of remedy;
257.97(c)(3)(v) Available capacity and location of needed treatment, storage, and disposal services	Not Applicable	Capacity and location of treatment, storage, and disposal services is not a factor for this alternative	Capacity and location of treatment, storage, and disposal services is unlikely to be a factor for this alternative	Available temporary on-site storage capacity for ~463K cy of CCR while composite liner is constructed is significant limiting factor	Off-site disposal capacity, facility logistical capacity, or the time required to develop the necessary off-site disposal and logistical capacity is a significant limiting factor.
COMMUNITY ACCEPTANCE - 40 CFR 257.97(c)(4)					
257.97(c)(4) The degree to which community concerns are addressed by a potential remedy (Anticipated)	To be determined based on input obtained through public meetings/outreach to be completed	To be determined based on input obtained through public meetings/outreach to be completed	To be determined based on input obtained through public meetings/outreach to be completed	To be determined based on input obtained through public meetings/outreach to be completed	To be determined based on input obtained through public meetings/outreach to be completed

Created by: LAB/SK Date: 6/20/2019
Last revision by: EJN Date: 8/9/2019
Checked by: TK Date: 9/12/2019

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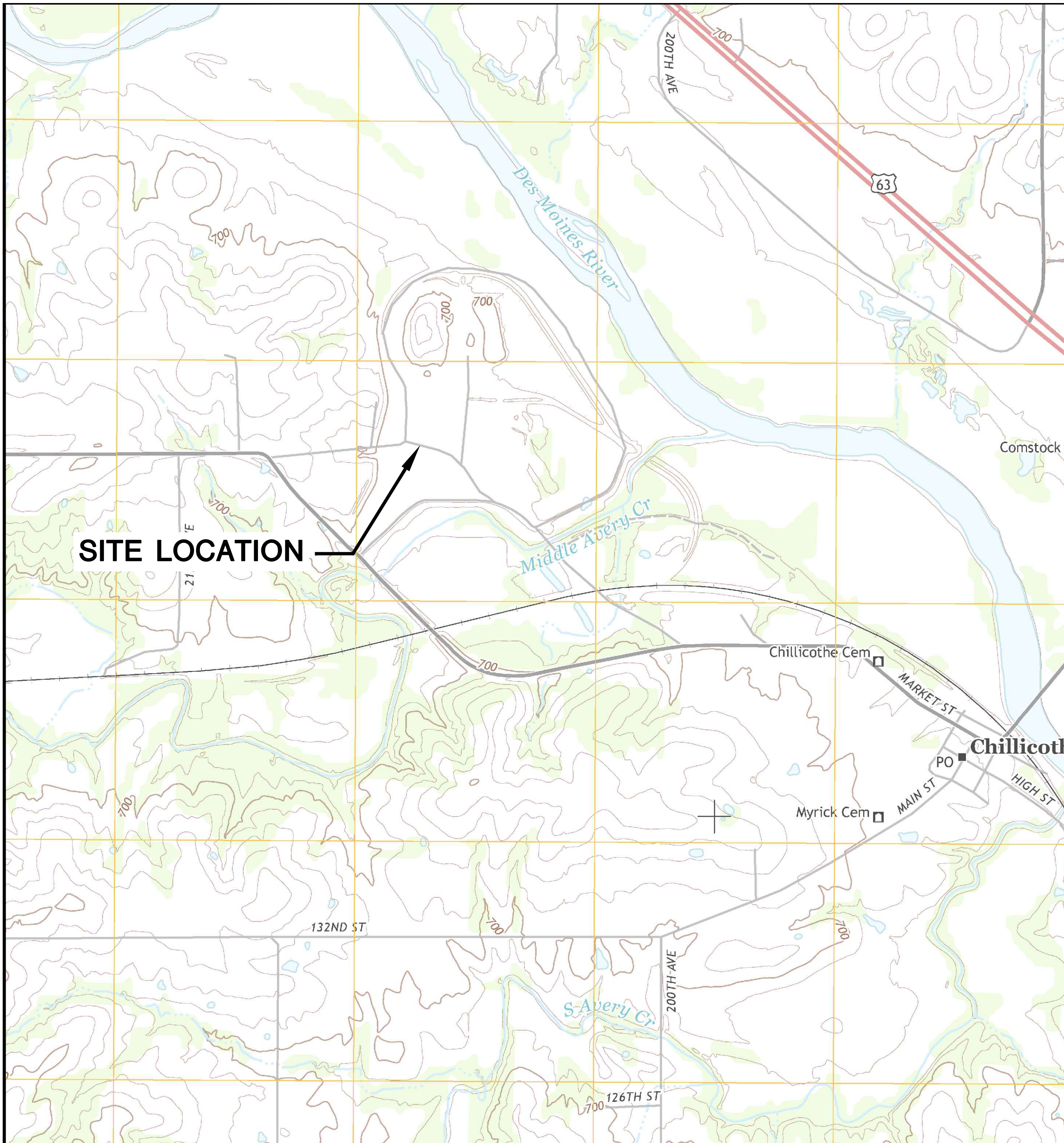
Figures



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CHILLICOTHE QUADRANGLE
IOWA–WAPELLO CO.
7.5 MINUTE SERIES (TOPOGRAPHIC)
2013
SCALE: 1" = 2,000'

IOWA

CLIENT	SITE	
INTERSTATE POWER AND LIGHT CO. 20775 POWER PLANT ROAD OTTUMWA, IA 52501	OTTUMWA GENERATING STATION OTTUMWA, IOWA	SITE LOCATION MAP

				ENGINEER	
PROJECT NO.	25218201.00	DRAWN BY:	AHB	SCS ENGINEERS 2830 DAIRY DRIVE MADISON, WI 53718-6751 PHONE: (608) 224-2830	FIGURE
DRAWN:	05/29/15	CHECKED BY:	KAK		1
REVISED:	03/08/16	APPROVED BY:	TJK 09/10/19		

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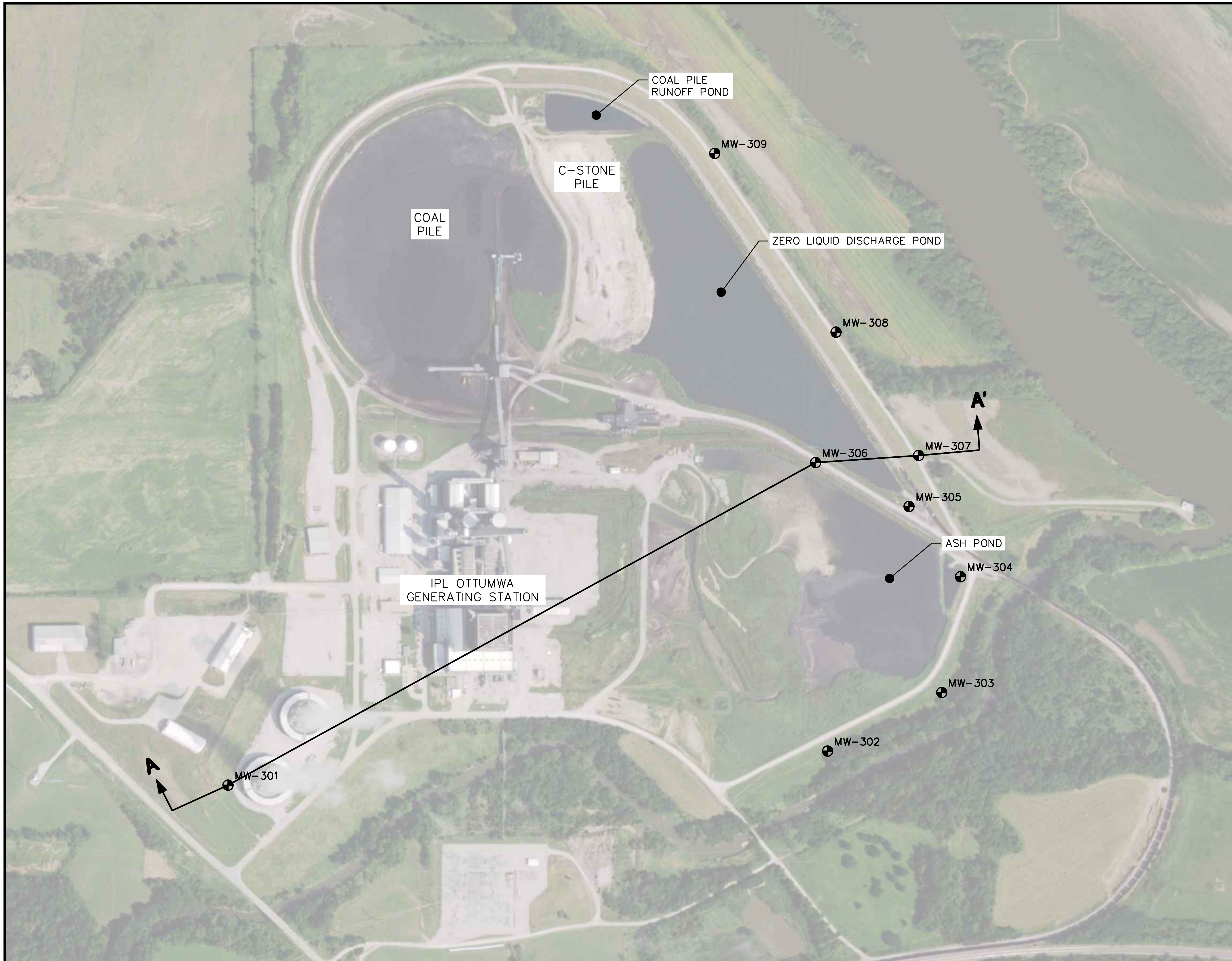


LEGEND

CCR MONITORING WELL LOCATION (APPROXIMATE)

GEOLOGIC CROSS SECTION

NOTES:

1. MONITORING WELLS MW-301 THROUGH MW-306 COMPRISE THE MONITORING SYSTEM FOR THE ASH POND. MONITORING WELLS MW-307 THROUGH MW-309 WERE ADDED TO MONITOR THE ZERO LIQUID DISCHARGE (ZLD) POND. MW-301 IS A SHARED BACKGROUND WELL FOR BOTH CCR UNITS.

N

500 0 500

SCALE: 1" = 500'

PROJECT NO.	25218201.00	DRAWN BY:	BSS
DRAWN:	07/03/19	CHECKED BY:	MDB
REVISED:	08/13/19	APPROVED BY:	TJK 09/10/19

ENGINEER: SCS ENGINEERS
2830 DAIRY DRIVE MADISON, WI 53718-6751
PHONE: (608) 224-2830

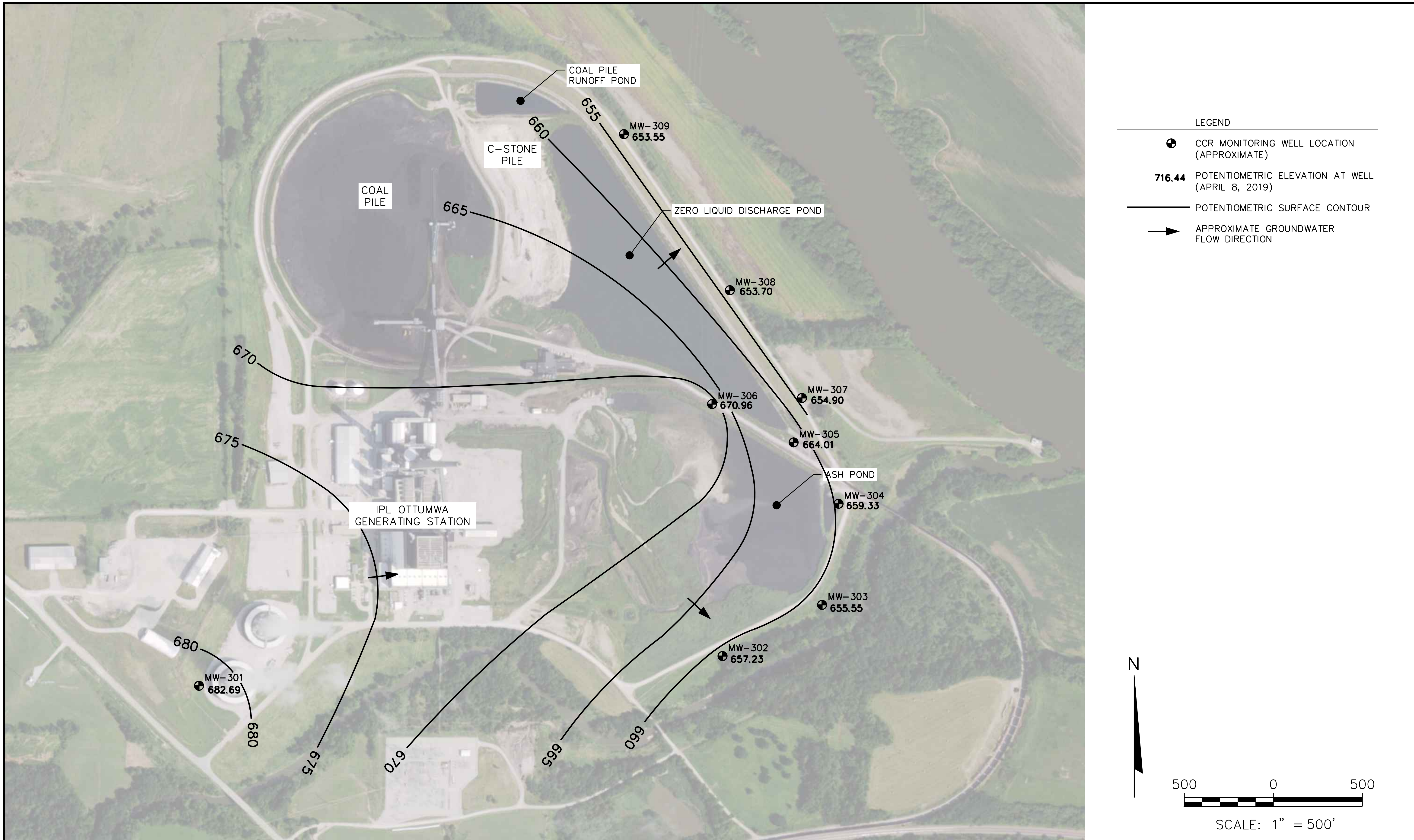
CLIENT: INTERSTATE POWER AND LIGHT CO.
15300 130th STREET
OTTUMWA, IA 52501

SITE: OTTUMWA GENERATING STATION
20775 POWER PLANT ROAD
OTTUMWA, IOWA

SITE PLAN AND MONITORING WELL LOCATIONS MAP

FIGURE 2

I:\25218201.00\Drawings\Ottumwa\2 Ottumwa Site Plan & Monitoring Well Location Map.dwg, 9/10/2019 1:48:04 PM



PROJECT NO.	25218201.00	DRAWN BY:	BSS	ENGINEER	SCS ENGINEERS 2830 DAIRY DRIVE MADISON, WI 53718-6751 PHONE: (608) 224-2830
DRAWN:	07/03/19	CHECKED BY:	NDK		
REVISED:	08/13/19	APPROVED BY:	TJK 09/10/19		

CLIENT	INTERSTATE POWER AND LIGHT CO. 15300 130th STREET OTTUMWA, IA 52501	SITE	OTTUMWA GENERATING STATION 20775 POWER PLANT ROAD OTTUMWA, IOWA	POTENTIOMETRIC SURFACE – APRIL 2019	FIGURE 3

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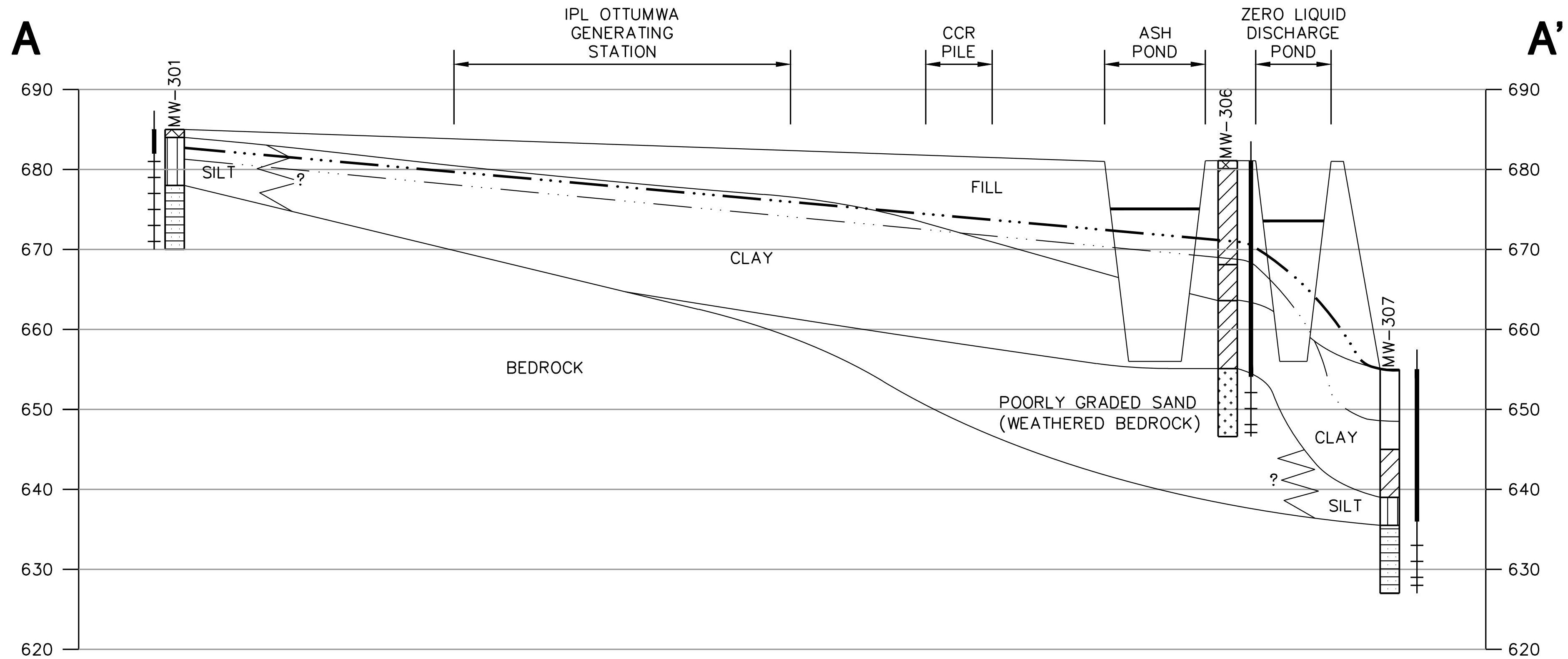
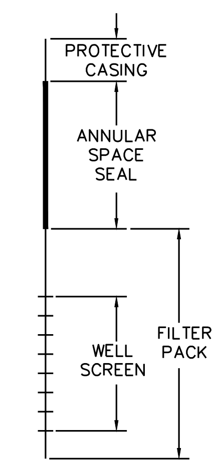


LEGEND

- TOPSOIL/FILL
- SAND, POORLY GRADED (SP)
- SILT, WITH SAND AND GRAVEL (ML)
- CLAY
- SANDSTONE
- HIGH POTENTIOMETRIC SURFACE MEASURED APRIL 2019
- LOW POTENTIOMETRIC SURFACE MEASURED AUGUST 2017
- POND SURFACE ELEVATION MEASURED JUNE 10-11, 2019



WELL DETAIL

0 500

HORIZONTAL SCALE: 1" = 500'
VERTICAL SCALE: 1" = 20'
VERTICAL EXAGGERATION = 25X

NOTES:

1. MW-307 WAS HYDROVACED TO APPROXIMATELY 8.5'. HYDROVACING IS PERFORMED TO DETERMINE IF UNDERGROUND UTILITIES ARE PRESENT. HIGH PRESSURE WATER AND A VACUUM ARE USED TO CLEAR THE BOREHOLE AND GEOLOGIC SAMPLES ARE NOT COLLECTED. NATIVE SOIL IN THE VICINITY OF MW-307 IS CLAY.

2. ASH POND AND ZLD POND BOTTOM ELEVATIONS ARE BASED ON THE EMBANKMENT CREST ELEVATION (681 FEET) AND INTERNAL STORAGE DEPTH (25 FEET) REPORTED IN THE HISTORY OF CONSTRUCTION REPORT ISSUED SEPTEMBER 29, 2016, BY HARD HAT SERVICES.

PROJECT NO.	25218201.00	DRAWN BY:	BSS
DRAWN:	07/03/19	CHECKED BY:	NDK/MDB
REVISED:	08/13/19	APPROVED BY:	TJK 09/10/19

ENGINEER: SCS ENGINEERS
2830 DAIRY DRIVE MADISON, WI 53718-6751
PHONE: (608) 224-2830

CLIENT: INTERSTATE POWER AND LIGHT CO.
15300 130th STREET
OTTUMWA, IA 52501

SITE: OTTUMWA GENERATING STATION
20775 POWER PLANT ROAD
OTTUMWA, IOWA

GEOLOGIC CROSS SECTION A-A'

FIGURE 4

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Appendix A

Regional Geological and Hydrogeological Information

Regional Hydrogeologic Stratigraphy
Ottumwa Generating Station / SCS Engineers Project #25215053.01

Age of Rocks	Hydrogeologic Unit	General Thickness (feet)	Name of Rock Unit*	Type of Rock
Quaternary (0-1 million years old)	Surficial Aquifers • Alluvial • Buried-Channel • Drift	0 to 320	Undifferentiated	• Sand, gravel, silt, and clay • Sand, gravel, silt, and clay • Till (sandy, pebbly clay), sand, and silt
Pennsylvanian (180 to 310 million years old)	Aquiclude	0 to 370	Undifferentiated	• Shale, sandstone, limestone, and coal
Mississippian (310 to 345 million years old	Mississippian Aquifer • Upper	0 to 600	St. Louis Spergen	• Limestone and sandstone • Limestone
	• Lower		Warsaw Keokuk Burlington Hampton Starrs Cave	• Shale and dolomite • Dolomite, limestone, and shale • Dolomite and limestone • Limestone and dolomite • Limestone
	Aquiclude	0 to 425	Prospect Hill McCraney	• Siltstone • Limestone
Devonian (345 to 400 million years old)			Yellow Spring Lime Creek	• Shale, dolomite, and siltstone • Dolomite and shale
	Devonian Aquifer	110 to 420	Cedar Valley Wapsipinicon	• Limestone and dolomite • Dolomite, limestone, shale, and gypsum
Silurian (400 to 425 million years old)		0 to 105	Undifferentiated	• Dolomite
Ordovician (425 to 500 million years old)	Aquiclude	150 to 600	Maquoketa Galena Decorah Platteville	• Dolomite and shale • Dolomite and chert • Limestone and shale • Limestone, shale, and sandstone
	Cambrian-Ordovician aquifer	750 to 1,110	St. Peter Prairie du Chien	• Sandstone • Dolomite and sandstone
Cambrian (500 to 600 million years old)			Jordan St. Lawrence	• Sandstone • Dolomite
	Not considered an aquifer in southeast Iowa	450 to 750+	Franconia Galesville Eau Claire Mt. Simon	• Shale, siltstone, and sandstone • Sandstone • Sandstone, shale, and dolomite • Sandstone
Precambrian (600 million to 2 billion + years old)				• Sandstone, igneous rocks, and metamorphic rocks

*This nomenclature and classification of rock units in this report are those of the Iowa Geological Survey and do not necessarily coincide with those accepted by the U.S. Geological Survey.

Source: "Water Resources of Southeast Iowa," Iowa Geologic Survey Water Atlas No. 4.

Appendix B

Boring Logs

SCS ENGINEERS **SOIL BORING LOG INFORMATION**

Environmental Consultants and Contractors

Route To: Watershed/Wastewater ☐ Waste Management ☐
Remediation/Redevelopment ☐ Other ☐

Facility/Project Name	License/Permit/Monitoring Number	Boring Number
IPL- Ottumwa Generating Station SCS#: 25215135.40		MW-301

Boring Drilled By: Name of crew chief (first, last) and Firm	Date Drilling Started	Date Drilling Completed	Drilling Method
Todd Schmalfeld Cascade Drilling	11/10/2015	11/10/2015	4-1/4 hollow stem auger

Unique Well No.	DNR Well ID No.	Common Well Name	Final Static Water Level	Surface Elevation	Borehole Diameter
		MW-301	Feet	684.3 Feet	8.5 in

Local Grid Origin ☐ (estimated: ☐) or Boring Location ☒
State Plane 400,077 N, 1,899,709 E S/C/N
NW 1/4 of SW 1/4 of Section 26, T 73 N, R 15 W
Lat ___ ° ___ ' ___ "
Long ___ ° ___ ' ___ "
Local Grid Location ☐ N ☐ E
Feet ☐ S Feet ☐ W

Facility ID	County	Civil Town/City/ or Village
	Wapello	Ottumwa

Sample Number and Type	Length Att. & Recovered (in)	Blow Counts	Depth In Feet	Soil/Rock Description And Geologic Origin For Each Major Unit	U S C S	Graphic Log	Well Diagram	PID/FID	Standard Penetration	Moisture Content	Liquid Limit	Plasticity Index	P 200	RQD/ Comments
			0–1	TOPSOIL.	TOPSOIL									
			1–7	SANDY SILT WITH GRAVEL, gray (7.5YR 6/1), gravel is fine.	ML									
S1	10	woh 1 3 9								W				
			7–15	WEATHERED SANDSTONE, very weak, light gray matrix (10YR 7/1), scondary color very dark gray 910YR 3/1), massive.	SANDSTONE									
S2	13	24 50								W				
S3	5	50								W				
S4	6	50								W				
S5	4	50								W				
			15	Endo of Boring at 15 feet bgs.										

I hereby certify that the information on this form is true and correct to the best of my knowledge.

Signature [signature] for Kyle Kramer

Firm SCS Engineers
2830 Dairy Drive Madison, WI 53718
Tel: (608) 224-2830
Fax:

SCS ENGINEERS
Environmental Consultants and Contractors

SOIL BORING LOG INFORMATION

Route To: Watershed/Wastewater ☐ Remediation/Redevelopment ☐ Waste Management ☐ Other ☐

Facility/Project Name		License/Permit/Monitoring Number		Boring Number	
IPL- Ottumwa Generating Station SCS#: 25215135.40				MW-302	
Boring Drilled By: Name of crew chief (first, last) and Firm		Date Drilling Started	Date Drilling Completed		Drilling Method
Todd Schmalfeld Cascade Drilling		11/10/2015	11/10/2015		4-1/4 hollow stem auger
Unique Well No.	DNR Well ID No.	Common Well Name	Final Static Water Level	Surface Elevation	Borehole Diameter
		MW-302	Feet	671.6 Feet	8.5 in

Local Grid Origin ☐ (estimated: ☐) or Boring Location ☒
State Plane 400,267 N, 1,902,625 E S/C/N
NE 1/4 of SE 1/4 of Section 26, T 73 N, R 15 W

Lat ___° ___' ___"
Long ___° ___' ___"

Local Grid Location ☐ N Feet ☐ S ☐ E Feet ☐ W

Facility ID	County	Civil Town/City/ or Village
	Wapello	Ottumwa

Sample Number and Type	Length Att. & Recovered (in)	Blow Counts	Depth In Feet	Soil/Rock Description And Geologic Origin For Each Major Unit	USCS	Graphic Log	Well Diagram	PID/FID	Standard Penetration	Moisture Content	Liquid Limit	Plasticity Index	P 200	RQD/ Comments
			0–1	TOPSOIL.	TOPSOIL									
			1–14	LEAN CLAY WITH SAND, dark gray (10YR 4/1).	CL									
S1	19	1 4 5 7	10–12							M				
S2	19	2 4 7 11	12.5–14.5							M				
			14–16	LEAN CLAY WITH SAND, very dark gray (5Y 3/1).	CL									

I hereby certify that the information on this form is true and correct to the best of my knowledge.

Signature: [signature] for Kyle Kramer

Firm: SCS Engineers
2830 Dairy Drive Madison, WI 53718
Tel: (608) 224-2830
Fax:

Boring Number MW-302

Sample: Number and Type	Sample: Length Att. & Recovered (in)	Blow Counts	Depth In Feet	Soil/Rock Description And Geologic Origin For Each Major Unit	U S C S	Graphic Log	Well Diagram	PID/FID	Soil Properties: Standard Penetration	Soil Properties: Moisture Content	Soil Properties: Liquid Limit	Soil Properties: Plasticity Index	Soil Properties: P 200	RQD/ Comments
S3	24	2 3 9 9	17	POORLY GRADED SAND, olive yellow (2.5Y 6/6).	SP					M				
			18	LEAN CLAY, dark grayish brown (10YR 4/2).	CL									
S4	24	4 4 4 4	19	POORLY GRADED GRAVEL, fine.	GP					W				saturation @ 18 ft bgs.
			20	LEAN CLAY, brownish yellow (10YR 6/8).	CL									
S5	15	2 3 3 6	21	POORLY GRADED GRAVEL WITH CLAY, gray (10YR 5/1), fine.	GP-GC					W				
			22											
S6	24	3 4 8 9	23							W				
			24	POORLY GRADED SAND, gray (10YR 5/1), medium grained.	SP									
			25											
S7	24	4 3 6 8	26							W				
			27											
			28	Same as above, but brown (10YR 5/3).										
S8	24	7 8 11 9	29	POORLY GRADED SAND, gray (10YR 5/1), fine grained, (weathered bedrock?).	SP					W				
			30	Medium grained.										
S9	23	5 14 33 50/.4	31							W				
			32											
S10	12	12 50/.3	33							W				
			34	POORLY GRADED SAND, olive yellow (2.5Y 7/1), fine grained, (weathered bedrock?).	SP									
			35											
S11	3	50/.3	36							W				
			37	End of Boring at 37 feet bgs.										

SCS ENGINEERS
Environmental Consultants and Contractors

SOIL BORING LOG INFORMATION

Route To: Watershed/Wastewater ☐ Waste Management ☐
Remediation/Redevelopment ☐ Other ☐

Facility/Project Name	License/Permit/Monitoring Number	Boring Number
IPL- Ottumwa Generating Station SCS#: 25215135.40		MW-303

Boring Drilled By: Name of crew chief (first, last) and Firm	Date Drilling Started	Date Drilling Completed	Drilling Method
Todd Schmalfeld Cascade Drilling	12/8/2015	12/8/2015	4-1/4 hollow stem auger

Unique Well No.	DNR Well ID No.	Common Well Name	Final Static Water Level	Surface Elevation	Borehole Diameter
		MW-303	Feet	659.0 Feet	8.5 in

Local Grid Origin ☐ (estimated: ☐) or Boring Location ☒
State Plane 400,583 N, 1,903,215 E S/C/N
NE 1/4 of SE 1/4 of Section 26, T 73 N, R 15 W
Lat ___° ___' ___"
Long ___° ___' ___"
Local Grid Location: Feet ☐ N ☐ S; Feet ☐ E ☐ W

Facility ID	County	Civil Town/City/ or Village
	Wapello	Ottumwa

Sample Number and Type	Length Att. & Recovered (in)	Blow Counts	Depth In Feet	Soil/Rock Description And Geologic Origin For Each Major Unit	U S C S	Graphic Log	Well Diagram	PID/FID	Standard Penetration	Moisture Content	Liquid Limit	Plasticity Index	P 200	RQD/ Comments
			0–9	FILL, boring location was cleared to 9' bgs by hydrovac, then back filled.	FILL									
			9–14.5	WEATHERED SANDSTONE, medium grained, brown (10YR 5/4).	SANDSTONE									
S1	1	50	~11							W				
S2	NR		~14											
			14.5	End of Boring at 14.5 ft bgs.										

I hereby certify that the information on this form is true and correct to the best of my knowledge.

Signature	Firm	
[signature] for Kyle Kramer	SCS Engineers 2830 Dairy Drive Madison, WI 53718	Tel: (608) 224-2830 Fax:

SCS ENGINEERS
Environmental Consultants and Contractors

SOIL BORING LOG INFORMATION

Route To: Watershed/Wastewater ☐ Waste Management ☐
Remediation/Redevelopment ☐ Other ☐

Facility/Project Name	License/Permit/Monitoring Number	Boring Number
IPL- Ottumwa Generating Station SCS#: 25215135.40		MW-304

Boring Drilled By: Name of crew chief (first, last) and Firm	Date Drilling Started	Date Drilling Completed	Drilling Method
Todd Schmalfeld Cascade Drilling	11/11/2015	11/11/2015	4-1/4 hollow stem auger

Unique Well No.	DNR Well ID No.	Common Well Name	Final Static Water Level	Surface Elevation	Borehole Diameter
		MW-304	Feet	680.1 Feet	8.5 in

Local Grid Origin ☐ (estimated: ☐) or Boring Location ☒
State Plane 401,152 N, 1,903,287 E S/C/N
SE 1/4 of NE 1/4 of Section 26, T 73 N, R 15 W

Lat ___° ___' ___"
Long ___° ___' ___"

Local Grid Location
Feet ☐ N ☐ S Feet ☐ E ☐ W

Facility ID	County	Civil Town/City/ or Village
	Wapello	Ottumwa

Sample Number and Type	Length Att. & Recovered (in)	Blow Counts	Depth In Feet	Soil/Rock Description And Geologic Origin For Each Major Unit	U S C S	Graphic Log	Well Diagram	PID/FID	Standard Penetration	Moisture Content	Liquid Limit	Plasticity Index	P 200	RQD/ Comments
			0–1	TOPSOIL.	TOPSOIL									
			1–12.5	FAT CLAY, black (10YR 2/1).	CH									
S1	23	4 5 4 5	11							M				
			12.5–15	FAT CLAY, yellowish brown (10YR 5/4).	CH									
S2	19.5	4 4 5 5	13.5							M				
			15–16	FAT CLAY, yellowish brown (10YR 3/4).	CH									

I hereby certify that the information on this form is true and correct to the best of my knowledge.

Signature	Firm	
[signature] for Kyle Kramer	SCS Engineers 2830 Dairy Drive Madison, WI 53718	Tel: (608) 224-2830 Fax:

Boring Number MW-304

Sample: Number and Type	Sample: Length Att. & Recovered (in)	Blow Counts	Depth In Feet	Soil/Rock Description And Geologic Origin For Each Major Unit	U S C S	Graphic Log	Well Diagram	PID/FID	Soil Properties: Standard Penetration	Soil Properties: Moisture Content	Soil Properties: Liquid Limit	Soil Properties: Plasticity Index	Soil Properties: P 200	RQD/ Comments
S3	12	3 3 4 5	17	FAT CLAY, yellowish brown (10YR 3/4). *(continued)*	CH					M				
S4	22	4 3 7 12	18–19							M				
S5	23	2 7 8 9	20–22							M				
S6	23	3 4 8 6	23–24							M				
S7	23	5 11 15 11	25–27							M				
S8	15	4 4 5 6	28–29							M				
S9	18	4 6 9 9	30–32							M				
S10	24	4 6 7 6	33–34							M				
S11	16	2 2 4 6	35–37	FAT CLAY, DARK OLIVE BROWN (2.5Y 3/3).	CH					M				
S12	24	4 3 5 5	38–39							M				
S13	18	2 3 3 3	40–42							M				

Boring Number MW-304

Sample: Number and Type	Sample: Length Att. & Recovered (in)	Blow Counts	Depth In Feet	Soil/Rock Description And Geologic Origin For Each Major Unit	U S C S	Graphic Log	Well Diagram	PID/FID	Soil Properties: Standard Penetration	Moisture Content	Liquid Limit	Plasticity Index	P 200	RQD/ Comments
			43	FAT CLAY, DARK OLIVE BROWN (2.5Y 3/3). *(continued)*	CH									
S14	24	3 4 9 14		SANDY SILT, very dark gray.	ML					W				
			44	POORLY GRADED SAND, medium grained, gray (5Y 6/1), (weathered bedrock).	SP									
			45											
S16	15	30 50/.4	46							W				
			47											
			48											
S17	5	33 50/.2								W				
			49											
			50											
S18		50/.4	51							W				
			52	End of Boring at 52 feet bgs.										

SCS ENGINEERS | **SOIL BORING LOG INFORMATION**

Environmental Consultants and Contractors

Route To: Watershed/Wastewater ☐ Waste Management ☐ Remediation/Redevelopment ☐ Other ☐

Facility/Project Name	License/Permit/Monitoring Number	Boring Number
IPL- Ottumwa Generating Station SCS#: 25215135.40		MW-305

Boring Drilled By: Name of crew chief (first, last) and Firm	Date Drilling Started	Date Drilling Completed	Drilling Method
Todd Schmalfeld Cascade Drilling	12/7/2015	12/8/2015	4-1/4 hollow stem auger

Unique Well No.	DNR Well ID No.	Common Well Name	Final Static Water Level	Surface Elevation	Borehole Diameter
		MW-305	Feet	681.5 Feet	8.5 in

Local Grid Origin ☐ (estimated: ☐) or Boring Location ☒
State Plane 401,473 N, 1,903,023 E S/C/N
SE 1/4 of NE 1/4 of Section 26, T 73 N, R 15 W

Lat ___° ___' ___" Long ___° ___' ___"

Local Grid Location: ☐ N ☐ E; Feet ☐ S; Feet ☐ W

Facility ID	County	Civil Town/City/ or Village
	Wapello	Ottumwa

Sample Number and Type	Length Att. & Recovered (in)	Blow Counts	Depth In Feet	Soil/Rock Description And Geologic Origin For Each Major Unit	U S C S	Graphic Log	Well Diagram	PID/FID	Standard Penetration	Moisture Content	Liquid Limit	Plasticity Index	P 200	RQD/ Comments
				TOPSOIL	TOPSOIL									
			1	GRAVEL	GP									
			2–9	FAT CLAY	CH									
			10	FAT CLAY, very dark grayish brown (10YR 3/2).										
S1	18	3 6 9 11	11							W				
			12											
			13	same as above except, brown (10YR 4/3).										
S2	22	3 7 14 22	14							W				
			15											
			16											

I hereby certify that the information on this form is true and correct to the best of my knowledge.

Signature	Firm	
(signature) for Kyle Kramer	SCS Engineers 2830 Dairy Drive Madison, WI 53718	Tel: (608) 224-2830 Fax:

Boring Number MW-305

Sample: Number and Type	Sample: Length Att. & Recovered (in)	Blow Counts	Depth In Feet	Soil/Rock Description And Geologic Origin For Each Major Unit	U S C S	Graphic Log	Well Diagram	PID/FID	Soil Properties: Standard Penetration	Soil Properties: Moisture Content	Soil Properties: Liquid Limit	Soil Properties: Plasticity Index	Soil Properties: P 200	RQD/ Comments
S3	22	5 15 14 15	17	FAT CLAY *(continued)*										
S4	20	3 5 13 15	18, 19		CH									
S5	24	4 5 7 11	20, 21, 22	FAT CLAY WITH SILT, dark gray (10YR 4/1).						M				
S6	20	7 11 15 20	23, 24	same as above except, very dark brown (10YR 2/2).						M				
S7	24	4 8 11 12	25, 26, 27	same as above except, very dark gray (10YR 3/1).	CH					M				
S8	24	8 12 16 21	28, 29							M				
S9	13	4 4 7 12	30, 31, 32							M				
S10	24	5 6 9	33, 34	LEAN CLAY, very dark brown (10YR 2/2).						W				
S11	24	4 4 5 7	35, 36, 37		CL					W				
S12	22	2 2 3 5	38, 39, 40	same as above except, very dark grayish brown (10YR 3/2).						W				
S13	6	3 9 11	41, 42	POORLY GRADED SANDY GRAVEL, fine, brown (10YR 4/3).	GPS					W				water @ 41.0 ft bgs.

Boring Number MW-305

Sample Number and Type	Length Att. & Recovered (in)	Blow Counts	Depth In Feet	Soil/Rock Description And Geologic Origin For Each Major Unit	U S C S	Graphic Log	Well Diagram	PID/FID	Standard Penetration	Moisture Content	Liquid Limit	Plasticity Index	P 200	RQD/ Comments
			43	POORLY GRADED SAND, medium grained, yellowish brown (10YR 5/4), (weathered bedrock). *(continued)*	SP									
S14	22	23 50	44							S				
			45											
S15	6	5 10 50	46		SP					S				
			47											
			48											
S16	6	50	49							S				
			50	End of Boring at 50 ft bgs.										

SCS ENGINEERS
Environmental Consultants and Contractors

SOIL BORING LOG INFORMATION

Route To: Watershed/Wastewater ☐ Waste Management ☐
Remediation/Redevelopment ☐ Other ☐

Facility/Project Name	License/Permit/Monitoring Number	Boring Number
IPL- Ottumwa Generating Station SCS#: 25215135.40		MW-306

Boring Drilled By: Name of crew chief (first, last) and Firm	Date Drilling Started	Date Drilling Completed	Drilling Method
Todd Schmalfeld Cascade Drilling	11/12/2015	11/12/2015	4-1/4 hollow stem auger

Unique Well No.	DNR Well ID No.	Common Well Name	Final Static Water Level	Surface Elevation	Borehole Diameter
		MW-306	Feet	681.1 Feet	8.5 in

Local Grid Origin ☐ (estimated: ☐) or Boring Location ☒
State Plane 401,666 N, 1,902,629 E S/C/N
SE 1/4 of NE 1/4 of Section 26, T 73 N, R 15 W

Lat ____ ° ____ ' ______ "
Long ____ ° ____ ' ______ "

Local Grid Location
Feet ☐ N ☐ S
Feet ☐ E ☐ W

Facility ID	County	Civil Town/City/ or Village
	Wapello	Ottumwa

Sample: Number and Type	Sample: Length Att. & Recovered (in)	Blow Counts	Depth In Feet	Soil/Rock Description And Geologic Origin For Each Major Unit	U S C S	Graphic Log	Well Diagram	PID/FID	Standard Penetration	Moisture Content	Liquid Limit	Plasticity Index	P 200	RQD/ Comments
			0–1	TOPSOIL.	TOPSOIL									
			1–13	FAT CLAY, dark olive brown (2.5Y 3/3).	CH									
S1	18	3 6 9 11	10–11.5							M				
			13–16	FAT CLAY, gray (10YR 5/1).	CH									
S2	22	5 6 7 9	12.5–14							M				

I hereby certify that the information on this form is true and correct to the best of my knowledge.

Signature	Firm	
[signature] for Kyle Kramer	SCS Engineers 2830 Dairy Drive Madison, WI 53718	Tel: (608) 224-2830 Fax:

Boring Number MW-306

Sample: Number and Type	Sample: Length Att. & Recovered (in)	Blow Counts	Depth In Feet	Soil/Rock Description And Geologic Origin For Each Major Unit	U S C S	Graphic Log	Well Diagram	PID/FID	Soil Properties: Standard Penetration	Soil Properties: Moisture Content	Soil Properties: Liquid Limit	Soil Properties: Plasticity Index	Soil Properties: P 200	RQD/ Comments
S3	22	5 10 10 14	17	FAT CLAY, gray (10YR 5/1). *(continued)* FAT CLAY, gray (10YR 5/1).	CH					M				
S4	13	5 8 14 17	18–19	FAT CLAY, dark olive brown (2.5Y 3/3).	CH					M				
S5	15	5 6 13 16	20–21							W				
S6	15	3 5 7 9	22–24							W				
S7	22	2 5 7 11	25–26	POORLY GRADED SAND, very dark grayish brown (10YR 3/2), medium to coarse grained, (weathered bedrock?).	SP					W				
S8	NR	7 3 4 3	27–29							W				
S9	18	1 1 2 2	30–31							W				
S10	13	WOR	32–34							W				
				End of Boring at 34.5 feet bgs.										

Appendix C

Information on Cobalt

ATSDR
AGENCY FOR TOXIC SUBSTANCES AND DISEASE REGISTRY

COBALT
CAS #7440-48-4

Division of Toxicology ToxFAQs™ **April 2004**

This fact sheet answers the most frequently asked health questions (FAQs) about cobalt. For more information, call the ATSDR Information Center at 1-888-422-8737. This fact sheet is one in a series of summaries about hazardous substances and their health effects. It is important you understand this information because this substance may harm you. The effects of exposure to any hazardous substance depend on the dose, the duration, how you are exposed, personal traits and habits, and whether other chemicals are present.

HIGHLIGHTS: The general population is exposed to low levels of cobalt in air, water, and food. Cobalt has both beneficial and harmful effects on health. At low levels, it is part of vitamin B12, which is essential for good health. At high levels, it may harm the lungs and heart. This chemical has been found in at least 426 of the 1,636 National Priorities List sites identified by the Environmental Protection Agency (EPA).

What is cobalt?
Cobalt is a naturally occurring element found in rocks, soil, water, plants, and animals. Cobalt is used to produce alloys used in the manufacture of aircraft engines, magnets, grinding and cutting tools, artificial hip and knee joints. Cobalt compounds are also used to color glass, ceramics and paints, and used as a drier for porcelain enamel and paints.

Radioactive cobalt is used for commercial and medical purposes. ^{60}Co (read as cobalt sixty) is used for sterilizing medical equipment and consumer products, radiation therapy for treating cancer patients, manufacturing plastics, and irradiating food. ^{57}Co is used in medical and scientific research. It takes about 5.27 years for half of ^{60}Co to give off its radiation and about 272 days for ^{57}Co; this is called the half-life.

What happens to cobalt when it enters the environment?
❑ Cobalt enters the environment from natural sources and the burning of coal or oil or the production of cobalt alloys.
❑ In the air, cobalt will be associated with particles that settle to the ground within a few days.
❑ Cobalt released into water or soil will stick to particles. Some cobalt compounds may dissolve.
❑ Cobalt cannot be destroyed. It can change form or attach to or separate from particles. Radioactive decay is a way of decreasing the amount of radioactive cobalt in the environment.

How might I be exposed to cobalt?
❑ You can be exposed to low levels of cobalt by breathing air, eating food, or drinking water. Food and drinking water are the largest sources of exposure to cobalt for the general population.
❑ Working in industries that make or use cutting or grinding tools; mine, smelt, refine, or process cobalt metal or ores; or that produce cobalt alloys or use cobalt.
❑ The general population is rarely exposed to radioactive cobalt unless a person is undergoing radiation therapy. However, workers at nuclear facilities, irradiation facilities, or nuclear waste storage sites may be exposed to radiation from these sources.

How can cobalt affect my health?
Cobalt can benefit or harm human health. Cobalt is beneficial for humans because it is part of vitamin B12.

Exposure to high levels of cobalt can result in lung and heart effects and dermatitis. Liver and kidney effects have also been observed in animals exposed to high levels of cobalt.

Exposure to large amounts of radiation from radioactive cobalt can damage cells in your body from the radiation.

You might also experience acute radiation syndrome that includes nausea, vomiting, diarrhea, bleeding, coma, and even death. This would be a rare event.

How likely is cobalt to cause cancer?

Nonradioactive cobalt has not been found to cause cancer in humans or animals following exposure in food or water. Cancer has been shown, however, in animals that breathed cobalt or when cobalt was placed directly into the muscle or under the skin. Based on the laboratory animal data, the International Agency for Research on Cancer (IARC) has determined that cobalt and cobalt compounds are possibly carcinogenic to humans.

Exposure to high levels of cobalt radiation can cause changes in the genetic materials within cells and may result in the development of some types of cancer.

How can cobalt affect children?

We do not know whether children differ from adults in their susceptibility to cobalt. However, it is likely that health effects in children would be similar those in adults. Studies in animals suggest that children may absorb more cobalt than adults from foods and liquids containing cobalt.

We do not know if exposure to cobalt will result in birth defects or other developmental effects in people. Birth defects have been observed in animals exposed to nonradioactive cobalt. Exposure to cobalt radiation can also result in developmental effects.

How can families reduce the risk of exposure to cobalt?

Children should avoid playing in soils near hazardous waste sites where cobalt may be present.

Is there a medical test to show whether I've been exposed to cobalt?

Cobalt levels can be tested in the urine and blood within a couple of days of exposure. Your doctor can take samples, but must send them to a laboratory to be tested. The amount of cobalt in your blood or urine can be used to estimate how much cobalt you were exposed to. However, these tests cannot predict whether you will experience any health effects.

Two types of tests are available for radioactive cobalt. One is to see if you have been exposed to a large dose of radiation, and the other is to see if radioactive cobalt is in your body. The first looks for changes in blood cell counts or in your chromosomes that occur at 3 to 5 times the annual occupational dose limit. It cannot tell if the radiation came from cobalt. The second type of test involves examining your blood, feces, saliva, urine, and even your entire body. It is to see if cobalt is being excreted from or remains inside your body. Either the doctor's office collects and sends the samples to a special lab for testing, or you must go to the lab for testing.

Has the federal government made recommendations to protect human health?

The Occupational Safety and Health Administration (OSHA) has set a limit of 0.1 milligrams of nonradioactive cobalt per cubic meter of workplace air (0.1 mg/m^3) for an 8-hour workday and 40-hour work week.

The Nuclear Regulatory Commission limits radioactive cobalt in workplace air to $1x10^{-5}$ microcurie per milliliter (µCi/mL) for ^{57}Co and $7x10^{-8}$ µCi/mL for ^{60}Co. EPA has set an average annual drinking water limit of 1000 picocurie per liter (pCi/L) for ^{57}Co or 100 pCi/L for ^{60}Co so the public radiation dose will not exceed 4 millirem.

Reference

Agency for Toxic Substances and Disease Registry (ATSDR). 2004. Toxicological Profile for Cobalt Atlanta, GA: U.S. Department of Health and Human Services, Public Health Service.

Where can I get more information? For more information, contact the Agency for Toxic Substances and Disease Registry, Division of Toxicology, 1600 Clifton Road NE, Mailstop F-32, Atlanta, GA 30333. Phone: 1-888-422-8737, FAX: 770-488-4178. ToxFAQs Internet address via WWW is http://www.atsdr.cdc.gov/toxfaq.html. ATSDR can tell you where to find occupational and environmental health clinics. Their specialists can recognize, evaluate, and treat illnesses resulting from exposure to hazardous substances. You can also contact your community or state health or environmental quality department if you have any more questions or concerns.

This Public Health Statement is the summary chapter from the Toxicological Profile for cobalt. It is one in a series of Public Health Statements about hazardous substances and their health effects. A shorter version, the ToxFAQs™, is also available. This information is important because this substance may harm you. The effects of exposure to any hazardous substance depend on the dose, the duration, how you are exposed, personal traits and habits, and whether other chemicals are present. For more information, call the ATSDR Information Center at 1-888-422-8737.

This public health statement tells you about cobalt and the effects of exposure.

The Environmental Protection Agency (EPA) identifies the most serious hazardous waste sites in the nation. These sites make up the National Priorities List (NPL) and are the sites targeted for long-term federal cleanup activities. Stable cobalt has been found in at least 426 of the 1,636 current or former NPL sites. Radioactive cobalt, as ^{60}Co, has been found in at least 13 of the 1,636 current or former NPL sites. However, the total number of NPL sites evaluated for this substance is not known. As more sites are evaluated, the sites at which cobalt is found may increase. This information is important because exposure to this substance may harm you and because these sites may be sources of exposure.

When a substance is released from a large area, such as an industrial plant, or from a container, such as a drum or bottle, it enters the environment. This release does not always lead to exposure. You are exposed to a substance only when you come in contact with it. You may be exposed by breathing, eating, or drinking the substance, or by skin contact.

External exposure to radiation may occur from natural or man-made sources. Naturally occurring sources of radiation are cosmic radiation from space or radioactive materials in soil or building materials. Man-made sources of radioactive materials are found in consumer products, industrial equipment, atom bomb fallout, and to a smaller extent from hospital waste and nuclear reactors.

If you are exposed to cobalt, many factors determine whether you'll be harmed. These factors include the dose (how much), the duration (how long), and how you come in contact with it. You must also consider the other chemicals you're exposed to and your age, sex, diet, family traits, lifestyle, and state of health.

1.1 WHAT IS COBALT?

Cobalt is a naturally-occurring element that has properties similar to those of iron and nickel. It has an atomic number of 27. There is only one stable isotope of cobalt, which has an atomic mass number of 59. (An element may have several different forms, called isotopes, with different weights depending on the number of neutrons that it contains. The isotopes of an element, therefore, have different atomic mass numbers [number of protons and neutrons], although the atomic number [number of protons] remains the same.) However, there are many unstable or radioactive isotopes, two of which are commercially important, cobalt-60 and cobalt-57, also written as Co-60 or ^{60}Co and Co-57 or ^{57}Co, and read as cobalt sixty and cobalt fifty-seven. All isotopes of cobalt behave the same chemically and will therefore have the same chemical behavior in the environment and the same chemical effects on your body. However, isotopes have different mass numbers and the radioactive isotopes have different radioactive properties, such as their half-life and the nature of the radiation they give off. The half-life of a cobalt isotope is the time that it takes for half of that isotope to give off its radiation and change into a different isotope. After one half-life, one-half of the radioactivity is gone. After a second half-life, one-fourth of the original radioactivity is left, and so on. Radioactive isotopes are constantly changing into different isotopes by giving off radiation, a process referred to as radioactive decay. The new isotope may be a different element or the same element with a different mass.

Small amounts of cobalt are naturally found in most rocks, soil, water, plants, and animals, typically in small amounts. Cobalt is also found in meteorites. Elemental cobalt is a hard, silvery grey metal. However, cobalt is usually found in the environment combined with other elements such as oxygen, sulfur, and arsenic. Small amounts of these chemical compounds can be found in rocks, soil, plants, and animals. Cobalt is even found in water in dissolved or ionic form, typically in small amounts. (Ions are atoms, collections of atoms, or molecules containing a positive or negative electric charge.) A biochemically important cobalt compound is vitamin B_{12} or cyanocobalamin. Vitamin B_{12} is essential for good health in animals and humans. Cobalt is not currently mined in the United States, but has been mined in the past. Therefore, we obtain cobalt and its other chemical forms from imported materials and by recycling scrap metal that contains cobalt.

Cobalt metal is usually mixed with other metals to form alloys, which are harder or more resistant to wear and corrosion. These alloys are used in a number of military and industrial applications such as aircraft engines, magnets, and grinding and cutting tools. They are also used in artificial hip and knee joints. Cobalt compounds are used as colorants in glass, ceramics, and paints, as catalysts, and as paint driers. Cobalt colorants have a characteristic blue color; however, not all cobalt compounds are blue. Cobalt compounds are also used as trace element additives in agriculture and medicine.

Cobalt can also exist in radioactive forms. A radioactive isotope of an element constantly gives off radiation, which can change it into an isotope of a different element or a different isotope of the same element. This newly formed nuclide may be stable or radioactive. This process is called radioactive decay. ^{60}Co is the most important radioisotope of cobalt. It is produced by bombarding natural cobalt, ^{59}Co, with neutrons in a nuclear reactor. ^{60}Co decays by giving off a beta ray (or electron), and is changed into a stable nuclide of nickel (atomic number 28). The half-life of ^{60}Co is 5.27 years. The decay is accompanied by the emission of high energy radiation called gamma rays. ^{60}Co is used as a source of gamma rays for sterilizing medical equipment and consumer products, radiation therapy for treating cancer patients, and for manufacturing plastics. ^{60}Co has also been used for food irradiation; depending on the radiation dose, this process may be used to sterilize food, destroy pathogens, extend the shelf-life of food, disinfest fruits and grain, delay ripening, and retard sprouting (e.g., potatoes and onions). ^{57}Co is used in medical and scientific research and has a half-life of 272 days. ^{57}Co undergoes a decay process called electron capture to form a stable isotope of iron (^{57}Fe). Another important cobalt isotope, ^{58}Co, is produced when nickel is exposed to a source of neutrons. Since nickel is used in nuclear reactors, ^{58}Co may be unintentionally produced and appear as a contaminant in cooling water released by nuclear reactors. ^{58}Co also decays by electron capture, forming another stable isotope of iron (^{58}Fe). ^{60}Co may be similarly produced from cobalt alloys in nuclear reactors and released as a contaminant in cooling water. ^{58}Co has a half-life of 71 days and gives off beta and gamma radiation in the decay process.

Quantities of radioactive cobalt are normally measured in units of radioactivity (curies or becquerels) rather than in units of mass (grams). The becquerel (Bq) is a new international unit, and the curie (Ci) is the traditional unit; both are currently used. A becquerel is the amount of radioactive material in which 1 atom transforms every second, and a curie is the amount of radioactive material in which 37 billion atoms transform every second. For an overview of basic radiation physics, chemistry, and biology see Appendix D of the cobalt profile. For more information on radiation, see the *ATSDR Toxicological Profile for Ionizing Radiation*.

1.2 WHAT HAPPENS TO COBALT WHEN IT ENTERS THE ENVIRONMENT?

Cobalt may enter the environment from both natural sources and human activities. Cobalt occurs naturally in soil, rock, air, water, plants, and animals. It may enter air and water, and settle on land from windblown dust, seawater spray, volcanic eruptions, and forest fires and may additionally get into surface water from runoff and leaching when rainwater washes through soil and rock containing cobalt. Soils near ore deposits, phosphate rocks, or ore smelting facilities, and soils contaminated by airport traffic, highway traffic, or other industrial pollution may contain high concentrations of cobalt. Small amounts of cobalt may be released into the atmosphere from coal-fired power plants and incinerators, vehicular exhaust, industrial activities relating to the mining and processing of cobalt-containing ores, and the production and use of cobalt alloys and chemicals. ^{58}Co and ^{60}Co may be released to the environment as a result of nuclear accidents (i.e, Chernobyl), radioactive waste dumping in the sea or from radioactive waste landfills, and nuclear power plant operations.

Cobalt cannot be destroyed in the environment. It can only change its form or become attached or separated from particles. Cobalt released from power plants and other combustion processes is usually attached to very small particles. Cobalt contained in windborne soil is generally found in larger particles than those released from power plants. These large particles settle to the ground or are washed out of the air by rain. Cobalt that is attached to very small particles may stay in the air for many days. Cobalt released into water may stick to particles in the water column or to the sediment at the bottom of the body of water into which it was released, or remain in the water column in ionic form. The specific fate of cobalt will depend on many factors such as the chemistry of the water and sediment at a site as well as the cobalt concentration and water flow. Cobalt deposited on soil is often strongly attached to soil particles and therefore would not travel very far into the ground. However, the form of the cobalt and the nature of the soil at a particular site will affect how far cobalt will penetrate into the soil. Both in soil and sediment, the amount of cobalt that is mobile will increase under more acidic conditions. Ultimately, most cobalt ends up in the soil or sediment.

Plants can accumulate very small amounts of cobalt from the soil, especially in the parts of the plant that you eat most often, such as the fruit, grain, and seeds. While animals that eat these plants will accumulate cobalt, cobalt is not known to biomagnify (produce increasingly higher concentrations) up the food chain. Therefore, vegetables, fruits, fish, and meat that you consume will generally not contain high amounts of cobalt. Cobalt is an essential element, required for good health in animals and humans, and therefore, it is important that foodstuffs contain adequate quantities of cobalt.

^{60}Co and ^{58}Co are moderately short-lived, manufactured radioactive isotopes that are produced in nuclear reactors. Although these isotopes are not produced by nuclear fission, small amounts of these radioisotopes are also produced by the neutron interaction with the structural materials found in the reactor of nuclear plants, and are produced during the routine operation of nuclear plants. Small amounts may be released to the environment as contaminants in cooling water or in radioactive waste. Since these isotopes are not fission products, they are not produced in nuclear weapons testing and are not associated with nuclear fallout. In the environment, radioactive isotopes of cobalt will behave chemically like stable cobalt. However, ^{60}Co and ^{58}Co will also undergo radioactive decay according to their respective half-lives, 5.27 years and 71 days.

1.3 HOW MIGHT I BE EXPOSED TO COBALT?

Cobalt is widely dispersed in the environment in low concentrations. You may be exposed to small amounts of cobalt by breathing air, drinking water, and eating food containing it. Children may also be exposed to cobalt by eating dirt. You may also be exposed by skin contact with soil, water, cobalt alloys, or other substances that contain cobalt.

Analytical methods used by scientists to determine the levels of cobalt in the environment generally do not determine the specific chemical form of cobalt present. Therefore, we do not always know the chemical form of cobalt to which a person may be exposed. Similarly, we do not know what forms of cobalt are present at hazardous waste sites. Some forms of cobalt may be insoluble or so tightly attached to particles or embedded in minerals that they are not taken up by plants and animals. Other forms of cobalt that are weakly attached to particles may be taken up by plants and animals.

The concentration of cobalt in soil varies widely, generally ranging from about 1 to 40 ppm (1 ppm=1 part of cobalt in a million parts of soil by weight), with an average level of 7 ppm. Soils containing less than about 3 ppm of cobalt are considered cobalt-deficient because plants growing in them do not have sufficient cobalt to meet the dietary requirements of cattle and sheep. Such cobalt-deficient soils are found in some areas in the southeast and northeast parts of the United States. On the other hand, soils near cobalt-containing mineral deposits, mining and smelting facilities, or industries manufacturing or using cobalt alloys or chemicals may contain much higher levels of cobalt.

Usually, the air contains very small amounts of cobalt, less than 2 nanograms (1 nanogram=one-billionth part of a gram) per cubic meter (ng/m^3). The amount of cobalt that you breathe in a day is much less than what you consume in food and water. You may breathe in higher levels of cobalt in dust in areas near cobalt-related industries or near certain hazardous waste sites.

The concentration of cobalt in surface and groundwater in the United States is generally low—

between 1 and 10 parts of cobalt in 1 billion parts of water (ppb) in populated areas; concentration may be hundreds or thousands times higher in areas that are rich in cobalt-containing minerals or in areas near mining or smelting operations. In most drinking water, cobalt levels are less than 1–2 ppb.

For most people, food is the largest source of cobalt intake. The average person consumes about 11 micrograms of cobalt a day in their diet. Included in this food is vitamin B_{12}, which is found in meat and diary products. The recommended daily intake of vitamin B_{12} is 6 micrograms (1 microgram=one-millionth part of a gram).

You may also be exposed to higher levels of cobalt if you work in metal mining, smelting, and refining, in industries that make or use cutting or grinding tools, or in other industries that produce or use cobalt metal and cobalt compounds. If good industrial hygiene is practiced, such as the use of exhaust systems in the workplace, exposure can be reduced to safe levels. Industrial exposure results mainly from breathing cobalt-containing dust.

When we speak of exposure to ^{60}Co, we are interested in exposure to the radiation given off by this isotope, primarily the gamma rays. The general population is rarely exposed to this radiation unless a person is undergoing radiation therapy. However, workers at nuclear facilities, irradiation facilities, or nuclear waste storage sites may be exposed to ^{60}Co or ^{58}Co. Exposures to radiation at these facilities are regulated and carefully monitored and controlled.

1.4 HOW CAN COBALT ENTER AND LEAVE MY BODY?

Cobalt can enter your body when you breathe in air containing cobalt dust, when you drink water that contains cobalt, when you eat food that contains cobalt, or when your skin touches materials that contain cobalt. If you breathe in air that contains cobalt dust, the amount of inhaled cobalt that stays in your lungs depends on the size of the dust particles. The amount that is then absorbed into your blood depends on how well the particles dissolve. If the particles dissolve easily, then it is easier for the cobalt to pass into your blood from the particles in your lungs. If the particles dissolve slowly, then they will remain in your lungs longer. Some of the particles will leave your lungs as they normally clean themselves out. Some of the particles will be swallowed into your stomach. The most likely way you will be exposed to excess cobalt is by eating contaminated food or drinking contaminated water. Levels of cobalt normally found in the environment, however, are not high enough to result in excess amounts of cobalt in food or water. The amount of cobalt that is absorbed into your body from food or water depends on many things including your state of health, the amount you eat or drink, and the number of days, weeks, or years you eat foods or drink fluids containing cobalt. If you do not have enough iron in your body, the body may absorb more cobalt from the foods you eat. Once cobalt enters your body, it is distributed into all tissues, but mainly into the liver, kidney, and bones. After cobalt is breathed in or eaten, some of it leaves the body quickly in the feces. The rest is absorbed into the blood and then into the tissues throughout the body. The absorbed cobalt leaves the body slowly, mainly in the urine. Studies have shown that cobalt does not readily enter the body through normal skin, but it can if the skin has been cut.

1.5 HOW CAN COBALT AFFECT MY HEALTH?

To protect the public from the harmful effects of toxic chemicals and to find ways to treat people who have been harmed, scientists use many tests.

One way to see if a chemical will hurt people is to learn how the chemical is absorbed, used, and released by the body. In the case of a radioactive chemical, it is also important to gather information concerning the radiation dose and dose rate to the body. For some chemicals, animal testing may be necessary. Animal testing may also be used to identify health effects such as cancer or birth defects. Without laboratory animals, scientists would lose a basic method to get information needed to make wise decisions to protect public health. Scientists have the responsibility to treat research animals with care and compassion. Laws today protect the welfare of research animals, and scientists must comply with strict animal care guidelines.

Cobalt has both beneficial and harmful effects on human health. Cobalt is beneficial for humans because it is part of vitamin B_{12}, which is essential to maintain human health. Cobalt (0.16–1.0 mg cobalt/kg of body weight) has also been used as a treatment for anemia (less than normal number of red blood cells), including in pregnant women, because it causes red blood cells to be produced. Cobalt also increases red blood cell production in healthy people, but only at very high exposure levels. Cobalt is also essential for the health of various animals, such as cattle and sheep. Exposure of humans and animals to levels of cobalt normally found in the environment is not harmful.

When too much cobalt is taken into your body, however, harmful health effects can occur. Workers who breathed air containing 0.038 mg cobalt/m^3 (about 100,000 times the concentration normally found in ambient air) for 6 hours had trouble breathing. Serious effects on the lungs, including asthma, pneumonia, and wheezing, have been found in people exposed to 0.005 mg cobalt/m^3 while working with hard metal, a cobalt-tungsten carbide alloy. People exposed to 0.007 mg cobalt/m^3 at work have also developed allergies to cobalt that resulted in asthma and skin rashes. The general public, however, is not likely to be exposed to the same type or amount of cobalt dust that caused these effects in workers.

In the 1960s, some breweries added cobalt salts to beer to stabilize the foam (resulting in exposures of 0.04–0.14 mg cobalt/kg). Some people who drank excessive amounts of beer (8–25 pints/day) experienced serious effects on the heart. In some cases, these effects resulted in death. Nausea and vomiting were usually reported before the effects on the heart were noticed. Cobalt is no longer added to beer so you will not be exposed from this source. The effects on the heart, however, may have also been due to the fact that the beer-drinkers had protein-poor diets and may have already had heart damage from alcohol abuse. Effects on the heart were not seen, however, in people with anemia treated with up to 1 mg cobalt/kg, or in pregnant women with anemia treated with 0.6 mg cobalt/kg. Effects on the thyroid were found in people exposed to 0.5 mg cobalt/kg for a few weeks. Vision problems were found in one man following treatment with 1.3 mg cobalt/kg for 6 weeks, but this effect has not been seen in other human or animal studies.

Being exposed to radioactive cobalt may be very dangerous to your health. If you come near radioactive cobalt, cells in your body can become damaged from gamma rays that can penetrate your entire body, even if you do not touch the radioactive cobalt. Radiation from radioactive cobalt can also damage cells in your body if you eat, drink, breathe, or touch anything that contains radioactive cobalt. The amount of damage depends on the amount of radiation to which you are exposed, which is related to the amount of activity in the radioactive material and the length of time that you are exposed. Most of the information regarding health effects from exposure to radiation comes from exposures for only short time periods. The risk of damage from exposure to very low levels of radiation for long time periods is not known. If you are exposed to enough radiation, you might experience a reduction in white blood cell number, which could lower your resistance to infections. Your skin might blister or burn, and you may lose hair from the exposed areas. This happens to cancer patients treated with large amounts of radiation to kill cancer. Cells in your reproductive system could become damaged and cause temporary sterility. Exposure to lower levels of radiation might cause nausea, and higher levels can cause vomiting, diarrhea, bleeding, coma, and even death. Exposure to radiation can also cause changes in the genetic materials within cells and may result in the development of some types of cancer.

Studies in animals suggest that exposure to high amounts of nonradioactive cobalt during pregnancy might affect the health of the developing fetus. Birth defects, however, have not been found in children born to mothers who were treated with cobalt for anemia during pregnancy. The doses of cobalt used in the animal studies were much higher than the amounts of cobalt to which humans would normally be exposed.

Nonradioactive cobalt has not been found to cause cancer in humans or in animals following exposure in the food or water. Cancer has been shown, however, in animals who breathed cobalt or when cobalt was placed directly into the muscle or under the skin. Based on the animal data, the International Agency for Research on Cancer (IARC) has determined that cobalt is possibly carcinogenic to humans.

Much of our knowledge of cobalt toxicity is based on animal studies. Cobalt is essential for the growth and development of certain animals, such as cows and sheep. Short-term exposure of rats to high levels of cobalt in the air results in death and lung damage. Longer-term exposure of rats, guinea pigs, hamsters, and pigs to lower levels of cobalt in the air results in lung damage and an increase in red blood cells. Short-term exposure of rats to high levels of cobalt in the food or drinking water results in effects on the blood, liver, kidneys, and heart. Longer-term exposure of rats, mice, and guinea pigs to lower levels of cobalt in the food or drinking water results in effects on the same tissues (heart, liver, kidneys, and blood) as well as the testes, and also causes effects on behavior. Sores were seen on the skin of guinea pigs following skin contact with cobalt for 18 days. Generally, cobalt compounds that dissolve easily in water are more harmful than those that are hard to dissolve in water.

Much of what we know about the effects of radioactive cobalt comes from studies in animals. The greatest danger of radiation seen in animals is the risk to the developing animal, with even moderate amounts of radiation causing changes in the fetus. High radiation doses in animals have also been shown to cause temporary or permanent sterility and changes in the lungs, which affected the animals' breathing. The blood of exposed animals has lower numbers of white blood cells, the cells that aid in resistance to infections, and red blood cells, which carry oxygen in the blood. Radioactive cobalt exposures in animals have also caused genetic damage to cells, cancer, and even death.

1.6 HOW CAN COBALT AFFECT CHILDREN?

This section discusses potential health effects from exposures during the period from conception to maturity at 18 years of age in humans.

Children can be exposed to cobalt in the same ways as adults. In addition, cobalt may be transferred from the pregnant mother to the fetus or from the mother to the infant in the breast milk. Children may be affected by cobalt the same ways as adults. Studies in animals have suggested that children may absorb more cobalt from foods and liquids containing cobalt than adults. Babies exposed to radiation while in their mother's womb are believed to be much more sensitive to the effects of radiation than adults.

1.7 HOW CAN FAMILIES REDUCE THE RISK OF EXPOSURE TO COBALT

If your doctor finds that you have been exposed to significant amounts of cobalt, ask whether your children might also be exposed. Your doctor might need to ask your state health department to investigate.

Since cobalt is naturally found in the environment, people cannot avoid being exposed to it. However, the relatively low concentrations present do not warrant any immediate steps to reduce exposure. If you are accidentally exposed to large amounts of cobalt, consult a physician immediately.

Children living near waste sites containing cobalt are likely to be exposed to higher environmental levels of cobalt through breathing, touching soil, and eating contaminated soil. Some children eat a lot of dirt. You should discourage your children from eating dirt. Make sure they wash their hands frequently and before eating. Discourage your children from putting their hands in their mouths or hand-to-mouth activity.

You are unlikely to be exposed to high levels of radioactive cobalt unless you are exposed as part of a radiotherapy treatment, there is an accident involving a cobalt sterilization or radiotherapy unit, or there is an accidental release from a nuclear power plant. In such cases, follow the advice of public health officials who will publish guidelines for reducing exposure to radioactive material when necessary. Workers who work near or with radioactive cobalt should follow the workplace safety guidelines of their institution carefully to reduce the risk of accidental irradiation.

1.8 IS THERE A MEDICAL TEST TO DETERMINE WHETHER I HAVE BEEN EXPOSED TO COBALT?

We have reliable tests that can measure cobalt in the urine and the blood for periods up to a few days after exposure. The amount of cobalt in your blood or urine can be used to estimate how much cobalt you had taken into your body. The tests are not able to accurately predict potential health effects following exposure to cobalt.

It is difficult to determine whether a person has been exposed only to external radiation from radioactive cobalt unless the radiation dose was rather large. Health professionals examining people who have health problems similar to those resulting from radiation exposure would need to rely on additional information in order to establish if such people had been near a source of radioactivity. It is relatively easy to determine whether a person has been internally exposed to radioactive cobalt.

1.9 WHAT RECOMMENDATIONS HAS THE FEDERAL GOVERNMENT MADE TO PROTECT HUMAN HEALTH?

The federal government develops regulations and recommendations to protect public health. Regulations can be enforced by law. Federal agencies that develop regulations for toxic substances include the Environmental Protection Agency (EPA), the Occupational Safety and Health Administration (OSHA), the Food and Drug Administration (FDA), and the U.S. Nuclear Regulatory Commission (USNRC).

Recommendations provide valuable guidelines to protect public health but cannot be enforced by law. Federal organizations that develop recommendations for toxic substances include the Agency for Toxic Substances and Disease Registry (ATSDR), the National Institute for Occupational Safety and Health (NIOSH), and the FDA.

Regulations and recommendations can be expressed in not-to-exceed levels in air, water, soil, or food that are usually based on levels that affect animals; they are then adjusted to help protect people. Sometimes these not-to-exceed levels differ among federal organizations because of different exposure times (an 8-hour workday or a 24-hour day), the use of different animal studies, or other factors.

Recommendations and regulations are also periodically updated as more information becomes available. For the most current information, check with the federal agency or organization that provides it. Some regulations and recommendations for cobalt include the following:

EPA requires that the federal government be notified if more than 1,000 pounds of cobalt (as the bromide, formate, and sulfamate compounds) are released into the environment in a 24-hour period. OSHA regulates levels of nonradioactive cobalt in workplace air. The limit for an 8-hour workday, 40-hour workweek is an average of 0.1 mg/m^3. The USNRC and the Department of Energy (DOE) regulate occupational exposures as well as exposures of the general public to radioactive cobalt.

1.10 WHERE CAN I GET MORE INFORMATION?

If you have any more questions or concerns, please contact your community or state health or environmental quality department, your regional Nuclear Regulatory Commission office, or contact ATSDR at the address and phone number below.

ATSDR can also tell you the location of occupational and environmental health clinics. These clinics specialize in recognizing, evaluating, and treating illnesses resulting from exposure to hazardous substances.

Toxicological profiles are also available on-line at www.atsdr.cdc.gov and on CD-ROM. You may request a copy of the ATSDR ToxProfiles CD-ROM by calling the information and technical assistance toll-free number at 1-888-42ATSDR (1-888-422-8737), by email at atsdric@cdc.gov, or by writing to:

Agency for Toxic Substances and Disease Registry
Division of Toxicology
1600 Clifton Road NE
Mailstop F-32
Atlanta, GA 30333
Fax: 1-770-488-4178

For-profit organizations may request a copy of final profiles from the following:

National Technical Information Service (NTIS)
5285 Port Royal Road
Springfield, VA 22161
Phone: 1-800-553-6847 or 1-703-605-6000
Web site: http://www.ntis.gov/