SGW-62439
Revision 0

EVALUATION OF CYANIDE TREATMENT WITHIN THE 200 WEST AREA GROUNDWATER TREATMENT FACILITY

Prepared for the U.S. Department of Energy
Assistant Secretary for Environmental Management

Contractor for the U.S. Department of Energy
under Contract DE-AC06-08RL14788

CH2MHILL
Plateau Remediation Company

P.O. Box 1600
Richland, Washington 99352

Approved for Public Release;
Further Dissemination Unlimited

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Terms

bgs	below ground surface
EPA	U. S. Environmental Protection Agency
FBR	fluidized bed reactor
IX	ion exchange
MBR	membrane bioreactor
MCL	maximum contaminant level
MTCA	Model Toxics Control Act
OU	operable unit
P&T	pump and treat
PQL	practical quantitation limit

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1 Introduction

The 200 West Area pump-and-treat (P&T) facility (hereinafter referred to as the 200 West P&T) began operating in July 2012 as one of the remedial action remedies for the 200-ZP-1 Operable Unit (OU) at the Hanford Site. The system has a maximum flow capacity of 9,500 L/min (2,500 gal/min), with a sustained nominal flow of 7,571 L/min (2,000 gal/min) when recirculation and downtime for operations and maintenance activities are considered. The 200 West P&T removes contaminants of concern from groundwater using ion exchange (IX), anoxic and aerobic bioreactors, membrane filtration, and air stripping. By 2016, the P&T system was also being used to treat contaminated groundwater from the 200-UP-1 and 200-BP-5 OUs, contaminated perched water from the 200-DV-1 OU, and leachate from the Environmental Restoration Disposal Facility. The water is treated at the 200 West P&T to meet injection criteria for protection of groundwater, and the treated water is then injected into the aquifer in the 200-ZP-1 and 200-UP-1 OUs. At the end of 2017, 31 extraction wells (in the 200-ZP-1, 200-UP-1, 200-BP-5, and 200-DV-1 OUs) and 29 injection wells were in use, and the 200 West P&T was operating at 7,436.2 L/min (1,963.2 gal/min) (Section 12.9.2 in DOE/RL-2017-66, *Hanford Site Groundwater Monitoring Report for 2017*).

1.1 Purpose

The purpose of this report is to assess whether treatment processes at the 200 West P&T are effective in removing free and total cyanide from groundwater sources (from both the 200 East Area and 200 West Area extraction wells feeding into the treatment plant) to meet injection criteria prior to injecting the treated groundwater into the 200-ZP-1 and 200-UP-1 OUs. Specifically, this report presents operations sampling data and removal efficiency calculations for each of the 200 West P&T treatment processes. This report is not intended to evaluate whether the treated water meets the criteria specified in supporting regulatory documents for injection into the aquifer.

1.2 History of the 200 West Pump and Treat

Since 2016, the 200 West P&T has received contaminated groundwater from the 200-ZP-1, 200-UP-1, and 200-BP-5 OUs; 200-DV-1 OU perched water; and Environmental Restoration Disposal Facility leachate. Each extraction and injection well has a specific well name (e.g., 299-E33-268) and a 200 West P&T identification number (e.g., YE-27). The 200 West P&T identification numbers begin with "YE-" for extraction wells and "YJ-" for injection wells (SGW-61013, *Cyanide Sampling at the 200 West Pump and Treat*).

Of all the regulatory documents for waste streams added to the 200 West P&T influent, only the action memorandum for the 200-BP-5 OU identifies cyanide as a contaminant of concern (DOE/RL-2016-41, *Action Memorandum for 200-BP-5 Operable Unit Groundwater Extraction*). When the 200 West P&T began treating 200-BP-5 OU groundwater, the treated water injected into the aquifer was required to meet injection criteria for cyanide. SGW-61013 provides a detailed discussion on the success in meeting the injection criteria.

1.3 Discharge Limits for Cyanide

The U.S. Environmental Protection Agency (EPA) established the maximum contaminant level (MCL) as 200 µg/L for free cyanide and allows for analysis of total cyanide for determining compliance with the *Safe Drinking Water Act* (EPA 815-B-16-012, *Cyanide Clarification of Free and Total Cyanide Analysis for Safe Drinking Water Act (SDWA) Compliance*). The MCL for cyanide is based on best available science to prevent potential health problems and also considers the cost, benefits, and the ability

of public water systems to detect and remove contaminants using suitable treatment technologies. A total cyanide concentration <200 µg/L can be reported as free cyanide <200 µg/L. Free cyanide analytical methods are used if the total cyanide concentration is >200 µg/L (SGW-61013).

The Washington State groundwater cleanup level is 4.8 µg/L for free cyanide analyzed as free cyanide. The state cleanup level is a risk-based concentration that is calculated using the reference dose and default exposure assumptions and equations in accordance with Model Toxics Control Act (MTCA) Method B (WAC 173-340, "Model Toxics Control Act—Cleanup"). This cleanup level considers possible health effects and exposure over a lifetime but does not consider the cost, benefits, or suitable treatment technologies (SGW-61013).

The action memorandum for the 200-BP-5 OU non-time-critical removal action lists the federal MCL for cyanide as 200 µg/L and indicates the state cleanup level is 4.8 µg/L (footnote b in Table 1 of DOE/RL-2016-41). The action memorandum does not specify that the federal MCL is for free cyanide analyzed as total cyanide and that the state MTCA Method B cyanide limit is for free cyanide analyzed as free cyanide rather than analyzed as total cyanide (SGW-61013). DOE/RL-2017-11, *Removal Action Work Plan for the 200-BP-5 Operable Unit Groundwater Extraction*, clarifies that the federal MCL (drinking water standard) and the state MTCA Method B cleanup level are for free cyanide.

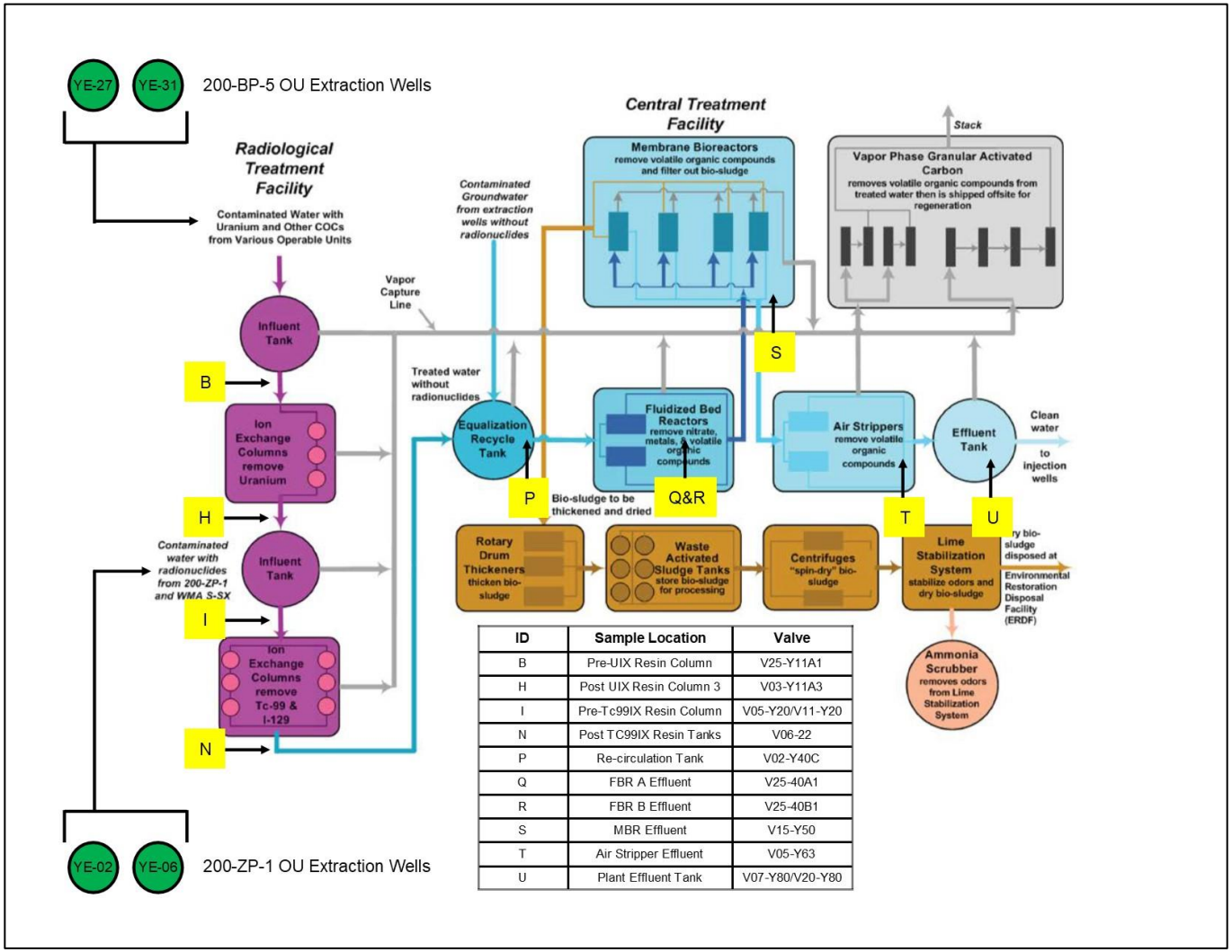
2 200 West Pump-and-Treat Processes

Four groundwater extraction wells are monitored by the 200 West P&T for free and total cyanide: two wells in the 200-BP-5 OU (200 East Area), and two wells in the 200-ZP-1 OU (200 West Area). This chapter discusses the free and total cyanide concentrations from these four wells (as well as any other possible sources) as groundwater moves through the P&T facility to show where cyanide is being removed from the water prior to injection into the aquifer underlying the 200 West Area. Figure 1 shows the 200 West P&T process and identifies the 2017 and 2018 cyanide sample locations. Appendix A presents the cyanide concentration data for operations samples collected from locations associated with the active treatment processes being assessed in this report.

2.1 Cyanide Source Water from the 200-BP-5 Operable Unit with Uranium Contamination

This section identifies the cyanide source wells in the 200-BP-5 OU that are currently being monitored by 200 West P&T operations. Groundwater extracted from these wells is also contaminated with uranium. These are the only wells currently being used for extraction of 200-BP-5 OU groundwater with treatment at the 200 West P&T.

Groundwater contamination in the 200-BP-5 OU is the result of >50 years of disposing large volumes of radioactive and nonradioactive liquid waste associated with operation of B Plant and other production and processing facilities at the Hanford Site.



ID	Sample Location	Valve
B	Pre-UIX Resin Column	V25-Y11A1
H	Post UIX Resin Column 3	V03-Y11A3
I	Pre-Tc99IX Resin Column	V05-Y20/V11-Y20
N	Post TC99IX Resin Tanks	V06-22
P	Re-circulation Tank	V02-Y40C
Q	FBR A Effluent	V25-40A1
R	FBR B Effluent	V25-40B1
S	MBR Effluent	V15-Y50
T	Air Stripper Effluent	V05-Y63
U	Plant Effluent Tank	V07-Y80/V20-Y80

Source: Modified from Figure 2.9 in DOE/RL-2016-69, *Calendar Year 2016 Annual Summary Report for the 200-ZP-1 and 200-UP-1 Operable Unit Pump-and-Treat Operations*.

Note: Valve V11-Y20 replaced valve V05-Y20 at the pre-technetium-99 ion-exchange resin ranks (sampling location "I") in July 2017. Valve V20-Y80 replaced valve V07-Y80 at the plant effluent tank (sampling location "U") in August 2017.

Figure 1. 200 West P&T Process Identifying Cyanide Sampling Locations in 2017 and 2018

2.1.1 YE-27 (299-E33-268)

Extraction well YE-27 (299-E33-268) is located west of the BY Tank Farm. The well was drilled to a total depth of 80.3 m (263.5 ft) below ground surface (bgs) in 2012 (SGW-52357, *Borehole Summary Report for the Installation of Two Wells in the 200-BP-5 Operable Unit, FY2012*).

2.1.2 YE-31 (299-E33-360)

Extraction well YE-31 (299-E33-360) is located north of the B Tank Farm. The well was drilled to a total depth of 83.1 m (272.8 ft) bgs in 2014 (SGW-58550, *Borehole Summary Report for the Installation of Five M-24 Groundwater Monitoring Wells, FY2014*).

2.2 Uranium System Inlet Tank (USIT-Y10)

USIT-Y10 is the interim holding tank for source water contaminated with uranium prior to being pumped to the uranium IX treatment process, which is described further in Section 2.3. Since this holding tank is not an active treatment process, Appendix A does not present data for this tank, and removal efficiencies are not calculated in Chapter 3 for this stage of the 200 West P&T.

2.3 Uranium Ion Exchange

The uranium IX treatment process is made up of three columns in series containing DOWEX® 21K resin, which is a Type 1 strong-base anion resin. The uranium ion exchanger has a nominal flow capacity of 1,136 L/min (300 gal/min) (1,515 L/min [400 gal/min] maximum) and was installed in the 200 West P&T in 2015. The ion exchanger treats uranium-contaminated water from the 200-UP-1, 200-DV-1, and 200-BP-5 OUs (DOE/RL-2016-69, *Calendar Year 2016 Annual Summary Report for the 200-ZP-1 and 200-UP-1 Operable Unit Pump-and-Treat Operations*). According to the EPA Drinking Water Treatability Database (EPA, 2009), IX is considered one of the best available technologies for the removal of cyanide from water.

Tables A-1 and A-2 in Appendix A summarize the operations sampling cyanide data that represent the influent and effluent concentrations for this treatment process.

2.4 Cyanide Source Water from the 200-ZP-1 Operable Unit with Technetium-99 Contamination

This section identifies the cyanide source wells in the 200-ZP-1 OU currently being monitored by the 200 West P&T. Groundwater extracted from these wells is also contaminated with technetium-99.

Groundwater contamination in the 200-ZP-1 OU is the result of >50 years of disposing large volumes of radioactive and nonradioactive liquid waste associated with operation of Z Plant and other production and processing facilities at the Hanford Site. Previous liquid waste disposal from these plants to the subsurface present the primary sources of groundwater contaminants in the 200 West Area.

2.4.1 YE-02 (299-W14-20)

Extraction well YE-02 (299-W14-20) is located east of the TX Tank Farm. The well was drilled to a total depth of 133.8 m (439 ft) bgs in 2009 (SGW-44641, *Borehole Summary Report for the Installation of Three Remedial Action Pump-and-Treat Wells for the 200-ZP-1 Operable Unit, FY2009*).

DOWEX® is a registered trademark of DOW Chemical Company, Midland, Michigan.

2.4.2 YE-06 (299-W11-50)

Extraction well YE-06 (299-W11-50) is located east of the T Tank Farm. The well was drilled to a total depth of 149.4 m (490 ft) bgs in 2011 (SGW-49573, *Borehole Summary Report for the Installation of 11 Remedial Action Groundwater Extraction and Injection Wells for the 200-ZP-1 Operable Unit*).

2.5 Technetium System Inlet Tank (TCSIT-Y99)

TCSIT-Y99 is the holding tank for source water that has been treated using uranium IX and for groundwater with technetium-99 contamination prior to being pumped to the technetium-99 IX treatment process, which is described further in Section 2.6. Since this holding tank is not an active part of the treatment process, Appendix A does not present data for this tank, and removal efficiencies are not calculated in Chapter 3 for this stage of the 200 West P&T.

2.6 Technetium-99 Ion Exchange

The technetium-99 IX treatment system is made up of six columns (two parallel sets of three) containing Purolite® A530E or Purolite A532E resin. Initially all vessels were loaded with Purolite A530E resin. As vessels become saturated, the old resin is removed and replaced with Purolite A532E resin because it is manufactured to have a greater selectivity for technetium-99. One vessel on the "B" train currently contains Purolite A532E. The technetium-99 ion exchangers remove technetium-99 and limited low concentrations of iodine-129 in contaminated groundwater from the 200-ZP-1, 200-UP-1, and 200-BP-5 OUs at a nominal flow capacity of 2,271 L/min (600 gal/min) (DOE/RL-2016-69). As mentioned in Section 2.3, the EPA considers IX a best available technology for the removal of cyanide from the water (EPA, 2009).

Tables A-3 and A-4 in Appendix A summarize the cyanide data from operations sampling that represent the influent and effluent concentrations for this treatment process.

2.7 Source Water from 200 East/200 West Areas Without Radioactive Contamination

There are no known cyanide source wells currently being monitored by the 200 West P&T without radioactive contamination.

2.8 Equalization and Recirculation Tank

The equalization tank is the interim holding and equalization tank for source water that has been treated using uranium IX and technetium-99 IX, and for water without radioactive contamination prior to being pumped to the fluidized bed reactors (FBRs) for treatment, which is further discussed in Section 2.9. The recirculation tank is immediately downstream of the equalization tank and receives water from internal plant recycle and wash-down water. Water from well development activities is also occasionally added to the recirculation tank. The recirculation tank serves as the influent source to the FBRs.

Cyanide data from operations sampling from the recirculation tank represent the influent concentrations to the FBR treatment process. Table A-5 in Appendix A summarizes the data. Since the recirculation tank is not an active treatment process, removal efficiencies are not calculated in Chapter 3 for this stage of the 200 West P&T.

Purolite® is a registered trademark of Brotech Corporation, Bala Cynwyd, Pennsylvania

2.9 Fluidized Bed Reactors and Membrane Bioreactors

Biological treatment in the 200 West P&T has a maximum flow capacity of 9,500 L/min (2,500 gal/min), with a sustained nominal flow of 7,571 L/min (2,000 gal/min) when recirculation and downtime for operation and maintenance activities are considered.

The FBR treatment system is made up of two parallel FBRs (A and B) that contain granular activated carbon for microorganisms to populate. The FBRs primarily remove nitrate, as well as some carbon tetrachloride and hexavalent chromium. The biological system has the capacity to biodegrade cyanide if necessary, but the concentration of cyanide has not been sufficient to maintain the correct population. The membrane bioreactors (MBRs) remove any remaining carbon substrate and filter the bacteria from the water.

Cyanide data from the recirculation tank (summarized in Table A-5 in Appendix A) represent the influent concentrations to the FBRs. Table A-6 in Appendix A summarizes the cyanide data from operations sampling that represent the effluent concentrations for the FBR treatment process, which are tracked separately for FBR A and FBR B. The FBR effluent cyanide data, when averaged from FBR A and FBR B, also represent the influent concentrations to the MBRs. Table A-7 in Appendix A summarizes the cyanide data from operations sampling that represent the effluent concentrations for the MBR treatment process. The MBR effluent cyanide data also represent the influent concentrations to the air-stripper treatment process, which is further discussed in Section 2.10.

2.10 Air Stripper

Treated water from the MBRs is pumped to the air-stripper treatment system to remove the remaining carbon tetrachloride and other volatile organic compounds that may have passed through the bioreactors. Free cyanide, a volatile compound, is also expected to be removed during this treatment process. The treatment system consists of two air-stripper columns (running in parallel), with the air-stripper exhaust passing through a granular activated carbon adsorption system to capture volatilized compounds. According to Dzombak et al., 2005, *Cyanide in Water and Soil: Chemistry, Risk, and Management*, it is possible to remove hydrogen cyanide from the water using an air stripper, although it is not considered a best available technology by the EPA (2009) or by Dzombak et al. (2005). The air-stripper effluent is then pumped to the plant effluent tank for injection into the aquifer underlying the 200 West Area.

Cyanide data from the MBR effluent (summarized in Table A-7 in Appendix A) represent the influent concentrations to the air strippers. Table A-8 in Appendix A summarizes the cyanide data from operations sampling that represent the effluent concentrations for the air-stripper treatment process.

2.11 Plant Effluent Tank

The plant effluent tank is the interim holding tank for treated groundwater before it is injected into the aquifer underlying the 200 West Area (200-ZP-1 and 200-UP-1 OUs) via injection wells.

Although the plant effluent tank is not an active treatment process for the 200 West P&T, the cyanide data from operations sampling are summarized in Table A-9 in Appendix A to further demonstrate the ability of the P&T system to meet the injection criteria for cyanide, as described in Section 1.3 and further discussed in SGW-61013.

3 Removal Efficiency Calculations

Removal efficiency (as it pertains to this report) is defined as a percentage of the influent cyanide that is removed from the process water. The primary calculation for removal efficiency is as follows:

$$Removal\ Efficiency = \left(\frac{CN\ Influent - CN\ Effluent}{CN\ Influent}\right) \times 100\%$$

where:

Removal efficiency	=	efficiency of the treatment process being performed (e.g., uranium IX, FBR, or air stripper) at removing cyanide from the water being treated
CN effluent	=	either the total cyanide effluent concentration or the free cyanide effluent concentration (depending on which calculation is being performed)
CN influent	=	either the total cyanide influent concentration or the free cyanide influent concentration (depending on which calculation in being performed)

To calculate the efficiency for this process, the above formula and the following assumptions were used:

- All undetectable concentrations were given a value of one-half of the reported detection limit for use in the removal efficiency calculation.
- If influent concentrations of total and/or free cyanide were undetectable prior to going into a treatment process, no removal efficiency calculation was made. This was noted as "not applicable" in the appropriate calculation tables.
- Only the highest standard reported value and lowest standard reported value (i.e., worst case or best case) of detectable concentrations of total and free cyanide (regardless of whether the sample was filtered, nonfiltered, duplicate or original) were used.
- Data flagged with a "Y" review qualifier were not used in the removal efficiency calculation. The "Y" review qualifier indicates that the result is suspect, and that review had insufficient evidence to show the result as valid or invalid. This was also noted as "not applicable" in the appropriate calculation tables.

The focus of this assessment is on each active treatment process, as demonstrated with operational sampling data collected from February 2017 to April 2018. The percent removal efficiency calculation is commonly used at water treatment plants to determine the performance of the plant and assess the amount of a contaminant removed.

Microsoft® Excel software was used to perform the removal efficiency calculations and support the results presented in this document. Microsoft Excel is a "site licensed client software" and is exempt from formal software control requirements. Development of the treatment efficiencies presented in this report involve simple calculations performed using Microsoft Excel spreadsheets.

Appendix A presents operations sampling data tables, and Appendix B provides the treatment process removal efficiency calculation results.

Microsoft® Excel is a registered product of the Microsoft Corporation, Redmond, Washington.

3.1 Uranium Ion-Exchange Removal Efficiency

Tables A-1 and A-2 in Appendix A summarize the data used for the removal efficiency calculations for this treatment process. After comparing the pre- and post-uranium IX cyanide concentrations, it is apparent that this process is very efficient at removing cyanide (both total and free) from the groundwater.

The calculations and resulting removal efficiency values using maximum and minimum concentration are presented in Tables B-1 and B-2 in Appendix B, respectively.

The average demonstrated removal efficiency for this treatment process regarding the highest and lowest reported values of total cyanide is 99.2%, ranging between 98.9% and 99.4%. The average demonstrated removal efficiency for this treatment process regarding the highest reported values of free cyanide is 72.8%, ranging between 61.6% and 79.1%. The average demonstrated removal efficiency for this treatment process regarding the lowest reported values of free cyanide is 64.9%, ranging between 61.8% and 67.9%.

3.2 Technetium-99 Ion-Exchange Removal Efficiency

Tables A-3 and A-4 in Appendix A summarize the data used for the removal efficiency calculations for this treatment process. After comparing the pre- and post-technetium-99 IX cyanide concentrations, it is apparent that this treatment process is very efficient at removing cyanide (both total and free) from groundwater.

The calculations and resulting removal efficiency values using maximum and minimum concentrations are presented Tables B-3 and B-4 in Appendix B, respectively.

The average demonstrated removal efficiency for this treatment process regarding the highest reported values of total cyanide is 66.1%, ranging between 14.7% and 84.1%. The average demonstrated removal efficiency for this treatment process regarding the highest reported values of free cyanide is 62.4%. The average demonstrated removal efficiency for this treatment process regarding the lowest reported values of free cyanide is 68.1%, ranging between 58.0% and 83.0%. All concentrations of the lowest reported values of free cyanide were undetectable pre- and post-process.

3.3 Fluidized Bed Reactor and Membrane Bioreactor Removal Efficiencies

Tables A-5 and A-6 in Appendix A summarize the data used for the removal efficiency calculations for the FBR treatment process. Data used for the removal efficiency calculations for the MBR process are summarized in Tables A-6 and A-7 in Appendix A. After comparing the pre- and post-FBR and MBR cyanide concentrations, it is apparent that there is not sufficient usable data to conclude whether these processes are effective in removing cyanide from the groundwater.

The calculations and resulting removal efficiency values for the FBR treatment process using maximum and minimum concentrations are presented in Tables B-5 and B-6 in Appendix B, respectively. The calculations and resulting removal efficiency values for the MBR treatment process (using maximum and minimum concentrations) are presented in Tables B-7 and B-8 in Appendix B, respectively.

The average demonstrated removal efficiency for the FBR treatment process regarding the highest reported values of total cyanide is -14%, ranging between -34.1% and 7.7%. The average demonstrated removal efficiency for the FBR treatment process regarding the highest reported values of free cyanide is 54.9%. The average demonstrated removal efficiency for the FBR treatment process regarding the lowest reported values of total cyanide is 23%, and the average demonstrated removal efficiency for the FBR treatment process regarding the lowest reported values of free cyanide is 65%.

The average demonstrated removal efficiency for the MBR treatment process regarding the highest reported values of total cyanide is 44%, ranging between 7.3% and 63.4%. The average demonstrated removal efficiency for the MBR treatment process regarding the highest reported values of free cyanide is -54.4%. The average demonstrated removal efficiency for the MBR treatment process regarding the lowest reported values of total cyanide is -25.6%, and the average demonstrated removal efficiency for the MBR treatment process regarding the lowest reported values of free cyanide is -126.5%.

Multiple anomalies were observed with the cyanide concentrations and the removal efficiency calculations regarding the FBR and MBR treatment processes, where higher cyanide concentrations were detected post-process than pre-process. The concentrations measured are typically between the minimum detectable level and the practical quantification limit (PQL) and are not reliable. In this range, the values for cyanide are typically ±50%. The uncertainty of cyanide concentrations at these low levels make quantitative calculation difficult. In addition, cyanide is potentially a natural byproduct of biological activity, and small quantities of cyanide could possibly be produced in the biological process.

3.4 Air Stripper Removal Efficiency

Tables A-7 and A-8 in Appendix A summarize the data used for the removal efficiency calculations for this treatment process. After comparing the pre- and post-air-stripper cyanide concentrations, this process appears to be relatively efficient in removing cyanide if the influent cyanide concentrations are low. Percent removal calculations were often not possible because the cyanide concentration in the influent to the air stripper were below detection. In other cases, the cyanide concentrations were less than the PQL and were of suspect quality. The low percent removals reflect the use of low concentrations that are often less than the PQL.

The calculations and resulting removal efficiency values using maximum and minimum concentrations are presented in Tables B-9 and B-10 in Appendix B, respectively.

The average demonstrated removal efficiency for this treatment process regarding the highest reported values of total cyanide is 16.6%, ranging between -4.5% and 52.3%. The average demonstrated removal efficiency for this treatment process regarding the highest reported values of free cyanide is 49%. The average demonstrated removal efficiency for this treatment process regarding the lowest reported values of total cyanide is 53.1%, and the average demonstrated removal efficiency for this treatment process regarding the lowest reported values of free cyanide is 76.6%.

Multiple anomalies were observed in the cyanide concentration data and the resulting removal efficiency calculations regarding the air-stripper treatment process, where higher cyanide concentrations were detected post-process than pre-process. With the data that are currently available, these anomalies are unexplainable. However, one anomaly that occurred on August 16, 2017, is suspected to be due to a questionable laboratory result. This result put concentrations of total and free cyanide more than one order of magnitude higher than any result observed before or since in that portion of the 200 West P&T. Because the laboratory results for August 16, 2017, are suspect, the cyanide concentrations pertaining to this date were not used in the efficiency calculations.

4 Conclusions

This report provides an evaluation of whether treatment processes within the 200 West P&T are effective in removing free and total cyanide from groundwater sources feeding into the treatment system. Using currently available operations sampling data, the removal efficiency calculations demonstrate that the IX treatment processes are very effective in removing both total and free cyanide from groundwater to meet 200 West P&T injection criteria. However, using the same evaluation tools, it is undeterminable

whether the FBR and MBR treatment processes are effective in removing cyanide from groundwater. Additional usable sample data are needed to make a defensible determination for the FBR and MBR processes. The air-stripper treatment process appears to be relatively effective if influent cyanide concentrations are low, although multiple anomalies with the concentration data discount that conclusion to some extent. A sufficient amount of adequate data is not available to draw conclusions for the air-stripper treatment process if higher influent concentrations of cyanide are present.

Many unexplainable anomalies (i.e., higher cyanide concentrations in post-process than pre-process) were observed in the data for this period. In the future, more usable and consistent data collected over a longer period of time may be helpful in explaining these anomalies and providing further understanding of the cyanide removal performance of the 200 West P&T treatment processes.

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Appendix A

Operations Sampling Data Tables
(Data Download: June 4, 2018)

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Table A-1. Pre-Uranium Ion-Exchange Cyanide Sampling Results

Sample Date	Total Cyanide	Amenable Cyanide	Total Iron Cyanide	Free Cyanide
Feb. 15, 2017	1.67 (U)	1.67 (U)	5.00 (U)	3.00 (U)
Mar. 1, 2017	122.00	19.00 (GH)	85.70 (*DN)	7.17 (BXGH)
Mar. 10, 2017	91.50/97.50	8.50/9.70	65.20 (N)	4.68 (B)/4.93 (B)
Mar. 15, 2017	102.00	17.10	53.50	6.14 (B)
Mar. 29, 2017	111.00	9.00	66.80 (H)	3.00 (U)
Apr. 12, 2017	103.00/99.60	1.67 U/1.67 (U)	67.30	3.00 (U)/3.00 (U)
Apr. 13, 2017	119.00	3.00 (B)	—	3.91 (B)
May 19, 2017	1.67 U/1.67 (U)	1.67 U/1.67 (U)	5.00 (U)	3.00 (U)/3.00 (U)
June 20, 2017	75.40/70.30	9.10/3.30 (B)	—	3.00 (U)/3.00 (U)
Aug. 16, 2017	103.00^{F}/100.00/107.00^{F}/104.00	1.67^{F} (U)/1.67 (U)/8.40^{F}/1.67 (U)	—	3.00^{F} (U)/3.00 (U)/3.00^{F} (U)/3.00 (U)
Oct. 23, 2017	1.67^{F} (U)/1.67 (U)/1.67^{F} U/1.67 (U)	1.67^{F} (U)/1.67 (U)/1.67^{F} (U)/1.67 (U)	—	3.00^{F} (U)/3.00 (U)/3.00^{F} (U)/3.00 (U)
Nov. 14, 2017	140.00/144.00^{F}	2.00 (B)/2.00^{F} (B)	—	3.00 (U)/3.00^{F} (U)
Dec. 13, 2017	138.00^{F}/136.00/136.00^{F}/138.00	1.67^{F} (U)/1.67 (U)/7.00^{F}/5.00	—	3.05^{F} (B)/3.00 (U)/3.00^{F} (U)/3.00 (U)
Jan. 18, 2018	105.00/98.40^{F}	46.20/9.50^{F}	—	3.00 (U)/3.00^{F} (U)
Feb. 13, 2018	102.00/106.00^{F}/101.00/104.00^{F}	5.30/13.30^{F}/8.00/10.20^{F}	—	3.00 (U)/3.00^{F} (U)/3.00 (U)/3.00^{F} (U)
Mar. 13, 2018	95.80/98.00^{F}	4.50 (B)/12.10^{F}	—	1.31 (B)/2.28^{F}
Apr. 23, 2018	107.00/110.00^{F}/119.00/113.00^{F}	74.90/44.10^{F}/119.00/113.00^{F}	—	1.00 (U)/1.00^{F} (U)/1.00 (U)/1.00^{F} (U)

Notes:
Samples were collected from valve V25-Y11A1, represented as location “B – Pre-UIX Resin Column” in Figure 1 in the main text.
Blank cells (—) indicate no result.
Sample results in µg/L.
F = filtered samples

Table A-1. Pre-Uranium Ion-Exchange Cyanide Sampling Results

Sample Date	Total Cyanide	Amenable Cyanide	Total Iron Cyanide	Free Cyanide

Data qualifiers:

* = relative percent difference for the matrix spike/matrix spike duplicate was out of limits

B = analyte was detected in both the associated method blank and the sample

D = analyte was determined using a secondary dilution factor greater than one; the primary preparation required additional dilution either to bring the analyte within the calibration range or to minimize interference

G = result has been reviewed through the request for data review process and determined to be correct, or the laboratory has supplied a corrected result after reviewing the original result or after reanalyzing the sample

H = laboratory holding time was exceeded before the sample was analyzed

N = matrix spike recovery is outside control limits; the associated sample data may be biased

U = constituent was analyzed for but not detected

X = indicates a result-specific comment is provided in the data report and/or case narrative

Table A-2. Post-Uranium Ion-Exchange Cyanide Sampling Results

Sample Date	Total Cyanide	Amenable Cyanide	Total Iron Cyanide	Free Cyanide
Feb. 15, 2017	3.60 (U)/1.67 (U)	1.67 (U)	—	3.00 (U)
Mar. 1, 2017	1.67 (U)	1.67 (U)	—	3.00 (U)
Mar. 10, 2017	1.67 (U)	1.67 (U)	—	3.00 (U)
Mar. 15, 2017	1.67 (U)	1.67 (U)	—	3.00 (U)
Mar. 29, 2017	1.67 (U)	1.67 (U)	—	3.00 (U)
Apr. 12, 2017	1.67 (U)	1.67 (U)	—	3.00 (U)
Apr. 13, 2017	1.67 (U)	1.67 (U)	—	3.00 (U)
May 19, 2017	1.67 (U)	1.67 (U)	—	3.00 (U)
June 20, 2017	1.67 (U)	1.67 (U)	—	3.00 (U)
Aug. 16, 2017	1.67^{F} (U)/1.67 (U)	1.67^{F} (U)/1.67 (U)	—	3.00^{F} (U)/3.00 (U)
Oct. 23, 2017	1.67^{F} (U)/1.67 (U)	1.67^{F} (U)/1.67 (U)	—	3.00^{F} (U)/3.00 (U)
Nov. 14, 2017	1.67 (U)/1.67^{F} (U)	1.67 (U)/1.67^{F} (U)	—	3.00 (U)/3.00^{F} (U)
Dec. 13, 2017	1.67^{F} (U)/1.67 (U)	1.67^{F} (U)/1.67 (U)	—	3.00^{F} (U)/3.00 (U)
Jan. 18, 2018	1.67 (U)/1.67^{F} (U)	1.67 (U)/1.67^{F} (U)	—	3.00 (U)/3.00^{F} (U)
Feb. 13, 2018	1.67 (U)/1.67^{F} (U)	1.67 (U)/1.67^{F} (U)	—	3.00 (U)/3.00^{F} (U)
Mar. 13, 2018	1.67 (U)/1.67^{F} (U)	1.67 (U)/1.67^{F} (U)	—	1.00 (U)/1.00^{F} (U)
Apr. 23, 2018	1.67 (U)/1.67^{F} (U)	1.67 (U)/1.67^{F} (U)	—	1.00 (U)/1.00^{F} (U)

Notes:

Samples were collected from valve V03-Y11A3, represented as location "H – Post-UIX Resin Column 3" in Figure 1 in the main text.

Blank cells (—) indicate no result.

Sample results in µg/L.

F = filtered samples

Data qualifiers:

U = constituent was analyzed for but not detected

Table A-3. Pre-Technetium-99 Ion-Exchange Cyanide Sampling Results

Sample Date	Total Cyanide	Amenable Cyanide	Total Iron Cyanide	Free Cyanide
Feb. 16, 2017	3.60 (U)/1.88 (B)/2.11 (B)	2.11 (B)/1.88 (B)	5.00 (U)	3.00 (U)/3.00 (U)
Mar. 1, 2017	3.22 (B)	1.67 (U)	5.00*(UN)	3.00 (U)
Mar. 10, 2017	2.31 (B)/2.33 (B)	1.67 (U)/1.67 (U)	5.89 (N)	3.00 (U)/3.00 (U)
Mar. 15, 2017	2.55 (B)	1.67 (U)	—	3.00 (U)
Mar. 29, 2017	1.82 (B)	1.82 (B)	12.00 (H)	3.00 (U)
Apr. 12, 2017	2.00 (B)/2.29 (B)	1.67 (U)/1.67 (U)	5.48	3.00 (U)/3.00 (U)
Apr. 13, 2017	2.29 (B)	1.67 (U)	—	3.00 (U)
May 19, 2017	2.86 (B)/2.99 (B)	1.67 (U)/1.67 (U)	5.00 (U)	3.00 (U)/3.00 (U)
June 20, 2017	2.74 (B)/2.54 (B)	1.67 (U)/1.67 (U)	—	3.00 (U)/3.00 (U)
Aug. 16, 2017	3.97^{F} (B)/4.00 (B)/3.95^{F} (B)/2.63 (B)	1.67 (U)/3.97^{F} (B)/1.67 (U)/1.67^{F} (U)	—	3.00^{F} (U)/3.00 (U)/3.00^{F} (U)/3.00 (U)
Oct. 23, 2017	3.72 ^{F} (B)/3.65 (B)/4.03^{F} (B)/3.64 (B)	1.67^{F} (U)/1.67 (U)/1.67^{F} (U)/1.67 (U)	—	3.00^{F} (U)/3.00 (U)/3.00^{F} (U)/3.00 (U)
Dec. 13, 2017	3.54^{F} (B)/3.58 (B)/3.80^{F} (B)/3.76 (B)	1.67^{F} (U)/1.67 (U)/1.67^{F} (U)/1.95 (B)	—	3.00^{F} (U)/3.00 (U)/3.00^{F} (U)/3.00 (U)
Feb. 14, 2018	1.72 (B)/1.99^{F} (B)/1.67 (U)/2.33^{F} (B)	1.67 (U)/1.67^{F} (U)/1.67 (U)/1.67^{F} (U)	—	3.00 (U)/3.00^{F} (U)/3.00 (U)/3.00^{F} (U)
Apr. 23, 2018	4.97 (B)/5.29^{F}/4.95 (B)/5.07^{F}	4.97 (B)/5.29^{F}/4.95 (B)/5.07^{F}	—	1.00 (U)/1.33^{F} (B)/1.00 (U)/1.33^{F} (B)

Notes:

Samples were collected from valves V05-Y20 and V11-Y20 (beginning in July 2017), represented as location "I – Pre-Tc-99 IX Resin Tanks" in Figure 1 in the main text.

Blank cells (—) indicate no result.

Sample results in µg/L.

F = filtered samples

Data qualifiers:

* = relative percent difference for the matrix spike/matrix spike duplicate pair was out of limits

B = analyte was detected in both the associated method blank and the sample

H = laboratory holding time was exceeded before the sample was analyzed

N = matrix spike recovery is outside control limits; the associated sample data may be biased

U = constituent was analyzed for but not detected

Table A-4. Post-Technetium-99 Ion-Exchange Cyanide Sampling Results

Sample Date	Total Cyanide	Amenable Cyanide	Total Iron Cyanide	Free Cyanide
Feb. 16, 2017	3.60 (U)/1.67 (U)	1.67 (U)	—	3.00 (U)
Mar. 1, 2017	1.67 (U)	1.67 (U)	—	3.00 (U)
Mar. 10, 2017	1.67 (U)	1.67 (U)	—	3.00 (U)
Mar. 15, 2017	1.67 (U)	1.67 (U)	—	3.00 (U)
Mar. 29, 2017	1.67 (U)	1.67 (U)	—	3.00 (U)
Apr. 12, 2017	1.67 (U)	1.67 (U)	—	3.00 (U)
Apr. 13, 2017	1.67 (U)	1.67 (U)	—	3.00 (U)
May 19, 2017	1.67 (U)	1.67 (U)	—	3.00 (U)
June 20, 2017	1.67 (U)	1.67 (U)	—	3.00 (U)
Aug. 16, 2017	1.67^{F} (U)/1.67 (U)	1.67^{F} (U)/1.67 (U)	—	3.00^{F} (U)/3.00 (U)
Oct. 23, 2017	1.67^{F} (U)/1.67 (U)	1.67^{F} (U)/1.67 (U)	—	3.00^{F} (U)/3.00 (U)
Dec. 13, 2017	1.67^{F} (U)/1.67 (U)	1.67^{F} (U)/1.67 (U)	—	3.00^{F} (U)/3.00 (U)
Feb. 13, 2018	1.67 (U)/1.67^{F} (U)	1.67 (U)/1.67^{F} (U)	—	3.00 (U)/3.00^{F} (U)
Apr. 23, 2018	1.67 (U)/1.67^{F} (U)	1.67 (U)/1.67^{F} (U)	—	1.00 (U)/1.00^{F} (U)

Notes:
Samples were collected from valve V06-Y22, represented as location "N – Post-Tc-99 IX Resin Tanks" in Figure 1 in the main text.
Blank cells (—) indicate no result.
Sample results in µg/L.
F = filtered samples
Data qualifiers:
U = constituent was analyzed for but not detected

Table A-5. Pre-Fluidized Bed Reactor Recirculation Tank Cyanide Sampling Results

Sample Date	Total Cyanide	Amenable Cyanide	Total Iron Cyanide	Free Cyanide
May 19, 2017	1.67 (U)	1.67 (U)	—	3.00 (U)
June 20, 2017	1.67 (U)	1.67 (U)	—	3.00 (U)
Aug. 16, 2017	1.67[F] (UY)/1.67 (U)	1.67[F] (UY)/1.67 (U)	—	3.00[F] (UY)/3.00 (U)
Oct. 23, 2017	1.67[F] (U)/1.67 (U)	1.67[F] (U)/1.67 (U)	—	3.00[F] (U)/3.00 (U)
Dec. 13, 2017	1.73[F] (B)/1.67 (U)	1.73[F] (B)/1.67 (U)	—	3.00[F] (U)/3.00 (U)
Feb. 15, 2018	1.67 (U)/1.67[F] (U)	1.67 (U)/1.67[F] (U)	—	3.00 (U)/3.00[F] (U)
Apr. 24, 2018	2.22 (B)/1.85[F] (B)	1.85[F] (B)/2.22 (B)	—	2.70 /3.08[F]

Notes:

Samples were collected from valve V02-Y40C, represented as location "P – Recirculation Tank" in Figure 1 in the main text.

Blank cells (—) indicate no result.

Sample results in µg/L.

F = filtered samples

Data qualifiers:

B = analyte was detected in both the associated method blank and the sample

U = constituent was analyzed for but not detected

Y = result is suspect; review had insufficient evidence to show result valid or invalid

Table A-6. Fluidized Bed Reactor Effluent Cyanide Sampling Results

FBR A					FBR B				
Sample Date	**Total Cyanide**	**Amenable Cyanide**	**Total Iron Cyanide**	**Free Cyanide**	**Sample Date**	**Total Cyanide**	**Amenable Cyanide**	**Total Iron Cyanide**	**Free Cyanide**
Apr. 13, 2017	11.60	8.80	—	3.00 (U)	Apr. 13, 2017	3.18 (B)	1.67 (U)	—	3.00 (U)
May 19, 2017	1.67 (U)	1.67 (U)	—	3.00 (U)	May 19, 2017	1.67 (U)	1.67 (U)	—	3.00 (U)
Aug. 16, 2017	2.60[F] (B)/ 1.67 (U)	2.60[F] (B)/ 1.67 (U)	—	3.00[F] (U)/ 3.00 (U)	—	—	—	—	—
Oct. 16, 2017	1.67[F] (U)/ 1.67 (U)	1.67[F] (U)/ 1.67 (U)	—	3.00[F] (U)/ 3.00 (U)	Oct. 23, 2017	1.67[F] (U)/ 1.67 (U)	1.67[F] (U)/ 1.67 (U)	—	3.00[F] (U)/ 3.00 (U)
Dec. 13, 2017	1.67[F] (U)/ 2.32 (B)	1.67[F] (U)/ 1.67 (U)	—	3.00[F] (U)/ 3.00 (U)	Dec. 13, 2017	1.67F (U)/ 2.27 (B)	1.67F (U)/ 1.67 (U)	—	3.00F (U)/ 3.00 (U)
Feb. 15, 2018	1.67 (U)/ 1.67[F] (U)	1.67 (U)/ 1.67[F] (U)	—	3.00 (U)/ 3.00[F] (U)	Feb. 15, 2018	1.67 (U)/ 1.67[F] (U)	1.67 (U)/ 1.67[F] (U)	—	3.00 (U)/ 3.00[F] (U)
Apr. 24, 2018	2.01 (B)/ 2.18[F] (B)	2.01 (B)/ 2.18[F] (B)	—	1.39 (B)/3.08[F]	Apr. 24, 2018	2.05 (B)/ 1.67[F] (U)	1.67[F] (U)/ 2.05 (B)	—	1.39 (B)/ 1.00[F] (U)

Notes:

FBR A samples were collected from valve V25-Y40A1, represented as location "Q – FBR A Effluent" in Figure 1 in the main text.

FBR B samples were collected from valve V25-Y40B1, represented as location "R – FBR B Effluent" in Figure 1 in the main text.

Blank cells (—) indicate no result.

Sample results in µg/L.

F = filtered samples

FBR = fluidized bed reactor

Data qualifiers:

B = analyte was detected in both the associated method blank and the sample

U = constituent was analyzed for but was detected

Table A-7. Membrane Bioreactor Effluent Cyanide Sampling Results

Sample Date	Total Cyanide	Amenable Cyanide	Total Iron Cyanide	Free Cyanide
Apr. 13, 2017	2.89 (B)	2.89 (B)	—	3.00 (U)
May 19, 2017	5.58	5.58	—	3.00 (U)
June 20, 2017	1.76 (B)	1.76 (B)	—	3.00 (U)
Aug. 16, 2017	134.00[F] (Y)/122.00 (Y)	132.00[F] (Y)/119.00 (Y)	—	98.10[F] (Y)/ 99.90 (Y)
Oct. 23, 2017	1.75[F] (B)/1.67 (U)	1.75[F] (B)/1.67 (U)	—	3.00[F] (U)/3.00 (U)
Dec. 13, 2017	1.67[F] (U)/1.67 (U)	1.67[F] (U)/1.67 (U)	—	3.00[F] (U)/3.00 (U)
Feb. 15, 2018	1.67 (U)/1.67[F] (U)	1.67 (U)/1.67[F] (U)	—	3.00 (U)/3.00[F] (U)
Apr. 24, 2018	1.79[F] (B)/1.96 (B)	1.96 (B)/1.79[F] (B)	—	3.45/2.14[F]

Notes:

Samples were collected from valve V15-Y50, represented as location "S – MBR Effluent" in Figure 1 in the main text.

Sample results in µg/L.

Blank cells (—) indicate no result.

F = filtered samples

Data qualifiers:

B = analyte was detected in both the associated method blank and the sample

U = the constituent was analyzed for but was not detected

Y = result is suspect; review had insufficient evidence to show result valid or invalid

Table A-8. Air Stripper Effluent Cyanide Sampling Results

Sample Date	Total Cyanide	Amenable Cyanide	Total Iron Cyanide	Free Cyanide
Apr. 13, 2017	3.02 (B)	3.02 (B)	—	3.00 (U)
May 19, 2017	6.09	6.09	—	3.13 (B)
June 20, 2017	1.67 (U)	1.67 (U)	—	3.00 (U)
Aug. 16, 2017	108.00[F] (Y)/107.00 (Y)	108.00[F] (Y)/105.00 (Y)	—	81.60[F] (Y)/78.60 (Y)
Oct. 23, 2017	1.67[F] (U)/1.67 (U)	1.67[F] (U)/1.67 (U)	—	3.00[F] (U)/3.00 (U)
Dec. 13, 2017	1.92[F] (B)/1.67 (U)	1.92[F] (B)/1.67 (U)	—	3.00[F] (U)/3.00 (U)
Feb. 15, 2018	1.67 (U)/1.67[F] (U)	1.67 (U)/1.67[F] (U)	—	3.00 (U)/3.00[F] (U)
Apr. 24, 2018	2.11 (B)/1.67[F] (U)	2.11 (B)/1.67[F] (U)	—	1.76 (B)/1.00[F] (U)

Notes:
Samples were collected from valve V05-Y63, represented as location "T – Air Stripper Effluent" in Figure 1 in the main text.
Sample results in μg/L.
Blank cells (—) indicate no result.
F = filtered samples
Data qualifiers:
B = analyte was detected in both the associated method blank and the sample
U = the constituent was analyzed for but not detected
Y = result is suspect; review had insufficient evidence to show result valid or invalid

Table A-9. Effluent Tank Cyanide Sampling Results

Sample Date	Total Cyanide	Amenable Cyanide	Total Iron Cyanide	Free Cyanide
Feb.15, 2017	5.9 (BC)/3.17 (B)/8.9 (BC)/3.21 (B)	3.17 (B)/3.21 (B)	—	3.00 (U)/3.00 (U)
Mar. 1, 2017	3.67 (B)/4.34 (B)	4.34 (B)/3.67 (B)	—	3.00 (U)/3.00 (U)
Mar. 10, 2017	1.67 (U)/1.67 (U)	1.67 (U)/1.67 (U)	—	3.00 (U)/3.00 (U)
Mar. 15, 2017	1.67 (U)/1.67 (U)	1.67 (U)/1.67 (U)	5.00 (U)	3.00 (U)/3.00 (U)
Mar. 29, 2017	7.12 (G)/7.16 (G)	7.12 (G)/7.16 (G)	5.00 (UH)	6.66 (BG)/6.03 (BG)
Apr. 12, 2017	1.67 (U)/1.67 (U)	1.67 (U)/1.67 (U)	—	3.00 (U)/3.00 (U)
Apr. 13, 2017	1.67 (U)/1.67 (U)	1.67 (U)/1.67 (U)	—	3.00 (U)/3.00 (U)
May 19, 2017	5.37/5.66	5.37/5.66	—	3.00 (U)/3.00 (U)
June 20, 2017	1.67 (U)/1.67 (U)	1.67 (U)/1.67 (U)	—	3.00 (U)/3.00 (U)
Aug. 16, 2017	2.68^{F} (B)/1.67 (U)/2.57 (B)/4.97 (B)	2.68^{F} (B)/1.67 (U)/2.57 (B)/4.97 (B)	—	3.00^{F} (U)/3.00 (U)/3.00 (U)/3.00 (U)
Sept. 6, 2017	1.67^{F} (U)/1.67 (U)/1.67^{F} (U)/1.67 (U)	1.67^{F} (U)/1.67 (U)/1.67^{F} (U)/1.67 (U)	—	3.00^{F} (U)/3.00 (U)/3.00^{F} (U)/3.00 (U)
Oct. 16, 2017	1.78^{F} (B)/1.67 (U)/1.91^{F} (B)/1.67 (U)	1.78^{F} (B)/1.67 (U)/1.91^{F} (B)/1.67 (U)	—	3.00^{F} (U)/3.00 (U)/3.00^{F} (U)/3.00 (U)
Nov. 11, 2017	2.25 (B)/2.04^{F} (B)/2.11 (B)/1.90^{F} (B)	1.67 (U)/1.67^{F} (U)/1.67 (U)/1.90^{F} (B)	—	3.00 (U)/3.00^{F} (U)/3.00 (U)/3.00^{F} (U)
Dec. 13, 2017	1.67^{F} (U)/1.67 (U)/1.80^{F} (B)/1.87 (B)	1.67^{F} (U)/1.67 (U)/1.80^{F} (B)/1.87 (B)	—	3.00^{F} (U)/3.00 (U)/3.00^{F} (U)/3.00 (U)
Jan. 17, 2018	1.67 (U)/1.67^{F} (U)/1.67 (U)/1.67^{F} (U)	1.67 (U)/1.67^{F} (U)/1.67 (U)/1.67^{F} (U)	—	3.00^{F} (U)/3.00 (U)/3.00^{F} (U)/3.00 (U)
Feb. 14, 2018	1.67 (U)/1.67^{F} (U)/1.67 (U)/1.67^{F} (U)	1.67 (U)/1.67^{F} (U)/1.67 (U)/1.67^{F} (U)	—	3.00 (U)/3.00^{F} (U)/3.00 (U)/3.00^{F} (U)
Mar. 13, 2018	3.73 (B)/11.20^{F}/4.02 (B)/10.30^{F}	3.73 (B)/11.20^{F}/4.02 (B)/10.30^{F}	—	2.77/2.52^{F}/2.52/3.01^{F}
Apr. 24, 2018	1.67 (U)/1.67^{F} (U)/1.92 (B)/1.67^{F} (U)	1.67 (U)/1.67^{F} (U)/1.92 (B)/1.67^{F} (U)	—	1.00 (U)/1.00^{F} (U)/2.14/ 1.00^{F} (U)

Notes:
Samples were collected from valves V07-Y80 and V20-Y80 (beginning in August 2017), represented as location "U – Plant Effluent Tank" in Figure 1 in the main text.
Sample results in μg/L.
Blank cells (—) indicate no result.
F = filtered samples

Table A-9. Effluent Tank Cyanide Sampling Results

Sample Date	Total Cyanide	Amenable Cyanide	Total Iron Cyanide	Free Cyanide

Data qualifiers:

B = analyte was detected in both the associated method blank and the sample

C = analyte was detected in both the sample and the method blank, and the sample concentration was <5 times the blank concentration

G = result has been reviewed through the request for data review process and determined to be correct, or the laboratory has supplied a corrected result after reviewing the original result or after reanalyzing the sample

H = laboratory holding time was exceeded before the sample was analyzed

U = constituent was analyzed for but not detected

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Appendix B

Treatment Process Removal Efficiency Calculation Results

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Tables

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Table B-1. Maximum Concentration: Total Cyanide Removal Efficiency/Free Cyanide Removal Efficiency – Uranium Ion Exchange

Pre-Uranium Ion Exchange			Post-Uranium Ion Exchange				
Date	Total Cyanide (µg/L)	Free Cyanide (µg/L)	Date	Total Cyanide (µg/L)	Free Cyanide (µg/L)	Removal Efficiency, Total Cyanide (%)	Removal Efficiency, Free Cyanide (%)
2/15/2017	1.80•	1.50•	2/15/2017	1.80•	1.50•	N/A	N/A
3/1/2017	122.00	7.17	3/1/2017	0.84•	1.50•	99.3	79.1
3/10/2017	97.50	4.93	3/10/2017	0.84•	1.50•	99.1	69.6
3/15/2017	102.00	6.14	3/15/2017	0.84•	1.50•	99.2	75.6
3/29/2017	111.00	1.50•	3/29/2017	0.84•	1.50•	99.2	N/A
4/12/2017	103.00	1.50•	4/12/2017	0.84•	1.50•	99.2	N/A
4/13/2017	119.00	3.91	4/13/2017	0.84•	1.50•	99.3	61.6
5/19/2017	0.84•	1.50•	5/19/2017	0.84•	1.50•	N/A	N/A
6/20/2017	75.40	1.50•	6/20/2017	0.84•	1.50•	98.9	N/A
8/16/2017	107.00	1.50•	8/16/2017	0.84•	1.50•	99.2	N/A
10/23/2017	0.84•	1.50•	10/23/2017	0.84•	1.50•	N/A	N/A
11/14/2017	144.00	1.50•	11/14/2017	0.84•	1.50•	99.4	N/A
12/13/2017	138.00	1.50•	12/13/2017	0.84•	1.50•	99.4	N/A
1/18/2018	105.00	1.50•	1/18/2018	0.84•	1.50•	99.2	N/A
2/13/2018	106.00	1.50•	2/13/2018	0.84•	1.50•	99.2	N/A
3/13/2018	98.00	2.28	3/13/2018	0.84•	1.50•	99.1	78.1
4/23/2018	119.00	0.50•	4/23/2018	0.84•	0.50•	99.3	N/A

• = undetectable concentration

N/A = not applicable

Table B-2. Minimum Concentration: Total Cyanide Removal Efficiency/Free Cyanide Removal Efficiency – Uranium Ion Exchange

Pre-Uranium Ion Exchange			Post-Uranium Ion Exchange				
Date	Total Cyanide (µg/L)	Free Cyanide (µg/L)	Date	Total Cyanide (µg/L)	Free Cyanide (µg/L)	Removal Efficiency, Total Cyanide (%)	Removal Efficiency. Free Cyanide (%)
2/15/2017	0.84•	1.50•	2/15/2017	0.84•	1.50•	N/A	N/A
3/1/2017	—	—	3/1/2017	0.84•	1.50•	—	—
3/10/2017	91.50	4.68	3/10/2017	0.84•	1.50•	99.1	67.9
3/15/2017	—	—	3/15/2017	0.84•	1.50•	—	—
3/29/2017	—	—	3/29/2017	0.84•	1.50•	—	—
4/12/2017	99.60	1.50•	4/12/2017	0.84•	1.50•	99.2	N/A
4/13/2017	—	—	4/13/2017	0.84•	1.50•	—	—
5/19/2017	0.84•	1.50•	5/19/2017	0.84•	1.50•	N/A	N/A
6/20/2017	70.30	1.50•	6/20/2017	0.84•	1.50•	98.8	N/A
8/16/2017	100.00	1.50•	8/16/2017	0.84•	1.50•	99.2	N/A
10/23/2017	0.84•	1.50•	10/23/2017	0.84•	1.50•	N/A	N/A
11/14/2017	140.00	1.50•	11/14/2017	0.84•	1.50•	99.4	N/A
12/13/2017	136.00	1.50•	12/13/2017	0.84•	1.50•	99.4	N/A
1/18/2018	98.40	1.50•	1/18/2018	0.84•	1.50•	99.1	N/A
2/13/2018	101.00	1.50•	2/13/2018	0.84•	1.50•	99.2	N/A
3/13/2018	95.80	1.31	3/13/2018	0.84•	0.50•	99.1	61.8
4/23/2018	107.00	0.50•	4/23/2018	0.84•	0.50•	99.2	N/A

— = no result
• = undetectable concentration
N/A = not applicable

Table B-3. Maximum Concentration: Total Cyanide Removal Efficiency/Free Cyanide Removal Efficiency – Technetium-99 Ion Exchange

Pre-Technetium-99 Ion Exchange			Post-Technetium-99 Ion Exchange				
Date	Total Cyanide (µg/L)	Free Cyanide (µg/L)	Date	Total Cyanide (µg/L)	Free Cyanide (µg/L)	Removal Efficiency, Total Cyanide (%)	Removal Efficiency, Free Cyanide (%)
2/16/2017	2.11	1.50•	2/16/2017	1.80•	1.50•	14.7	N/A
3/1/2017	3.22	1.50•	3/1/2017	0.84•	1.50•	73.9	N/A
3/10/2017	2.33	1.50•	3/10/2017	0.84•	1.50•	63.9	N/A
3/15/2017	2.55	1.50•	3/15/2017	0.84•	1.50•	67.1	N/A
3/29/2017	1.82	1.50•	3/29/2017	0.84•	1.50•	53.8	N/A
4/12/2017	2.29	1.50•	4/12/2017	0.84•	1.50•	63.3	N/A
4/13/2017	2.29	1.50•	4/13/2017	0.84•	1.50•	63.3	N/A
5/19/2017	2.99	1.50•	5/19/2017	0.84•	1.50•	71.9	N/A
6/20/2017	2.74	1.50•	6/20/2017	0.84•	1.50•	69.3	N/A
8/16/2017	4.00	1.50•	8/16/2017	0.84•	1.50•	79.0	N/A
10/23/2017	4.03	1.50•	10/23/2017	0.84•	1.50•	79.2	N/A
11/14/2017	—	—	11/14/2017	—	—	—	—
12/13/2017	3.80	1.50•	12/13/2017	0.84•	1.50•	77.9	N/A
1/18/2018	—	—	1/18/2018	—	—	—	—
2/14/2018	2.33	1.50•	2/14/2018	0.84•	1.50•	63.9	N/A
3/13/2018	—	—	3/13/2018	—	—	—	—
4/23/2018	5.29	1.33	4/23/2018	0.84•	0.50•	84.1	62.4

— = no result
• = undetectable concentration
N/A = not applicable

Table B-4. Minimum Concentration: Total Cyanide Removal Efficiency/Free Cyanide Removal Efficiency – Technetium-99 Ion Exchange

Pre-Technetium-99 Ion Exchange			Post-Technetium-99 Ion Exchange				
Date	Total Cyanide (µg/L)	Free Cyanide (µg/L)	Date	Total Cyanide (µg/L)	Free Cyanide (µg/L)	Removal Efficiency, Total Cyanide (%)	Removal Efficiency, Free Cyanide (%)
2/16/2017	1.80•	1.50•	2/16/2017	0.84•	1.50•	N/A	N/A
3/1/2017	—	—	3/1/2017	—	—	—	—
3/10/2017	2.31	1.50•	3/10/2017	0.84•	1.50•	63.6	N/A
3/15/2017	—	—	3/15/2017	—	—	—	—
3/29/2017	—	—	3/29/2017	—	—	—	—
4/12/2017	2.00	1.50•	4/12/2017	0.84•	1.50•	58.0	N/A
4/13/2017	—	—	4/13/2017	—	—	—	—
5/19/2017	2.86	1.50•	5/19/2017	0.84•	1.50•	70.6	N/A
6/20/2017	2.54	1.50•	6/20/2017	0.84•	1.50•	66.9	N/A
8/16/2017	2.63	1.50•	8/16/2017	0.84•	1.50•	68.1	N/A
10/23/2017	3.64	1.50•	10/23/2017	0.84•	1.50•	76.9	N/A
11/14/2017	—	—	11/14/2017	—	—	—	—
12/13/2017	3.54	1.50•	12/13/2017	0.84•	1.50•	76.3	N/A
1/18/2018	—	—	1/18/2018	—	—	—	—
2/14/2018	1.67	1.50•	2/14/2018	0.84•	1.50•	49.7	N/A
3/13/2018	—	—	3/13/2018	—	—	—	—
4/23/2018	4.95	0.50•	4/23/2018	0.84•	0.50•	83.0	N/A

— = no result
• = undetectable concentration
N/A = not applicable

Table B-5. Maximum Concentration: Total Cyanide Removal Efficiency/Free Cyanide Removal Efficiency – Fluidized Bed Reactor

Pre-Fluidized Bed Reactor			Post-Fluidized Bed Reactor A					Post-Fluidized Bed Reactor B				
Date	Total Cyanide (µg/L)	Free Cyanide (µg/L)	Date	Total Cyanide (µg/L)	Free Cyanide (µg/L)	Removal Efficiency, Total Cyanide (%)	Removal Efficiency, Free Cyanide (%)	Date	Total Cyanide (µg/L)	Free Cyanide (µg/L)	Removal Efficiency, Total Cyanide (%)	Removal Efficiency, Free Cyanide (%)
4/13/2017	—	—	4/13/2017	11.60	1.50•	—	—	4/13/2017	3.18	1.50•	—	—
5/19/2017	0.84•	1.50•	5/19/2017	0.84•	1.50•	N/A	N/A	5/19/2017	0.84•	1.50•	N/A	N/A
6/20/2017	0.84•	1.50•	6/20/2017	—	—	—	—	6/20/2017	—	—	—	—
8/16/2017	0.84•	1.50•	8/16/2017	2.60	1.50•	N/A	N/A	8/16/2017	—	—	—	—
10/23/2017	0.84•	1.50•	10/16/2017	0.84•	1.50•	N/A	N/A	10/23/2017	0.84•	1.50•	N/A	N/A
11/14/2017	—	—	11/14/2017	—	—	—	—	11/14/2017	—	—	—	—
12/13/2017	1.73	1.50•	12/13/2017	2.32	1.50•	-34.1	N/A	12/13/2017	2.27	1.50•	-31.2	N/A
1/18/2018	—	—	1/18/2018	—	—	—	—	1/18/2018	—	—	—	—
2/15/2018	0.84•	1.50•	2/15/2018	0.84•	1.50•	N/A	N/A	2/15/2018	0.84•	1.50•	N/A	N/A
3/13/2018	—	—	3/13/2018	—	—	—	—	3/13/2018	—	—	—	—
4/24/2018	2.22	3.08	4/24/2018	2.18	3.08	1.8	0.0	4/24/2018	2.05	1.39	7.7	54.9

— = no result
• = undetectable concentration
N/A = not applicable

Table B-6. Minimum Concentration: Total Cyanide Removal Efficiency/Free Cyanide Removal Efficiency – Fluidized Bed Reactor

Pre-Fluidized Bed Reactor			Post-Fluidized Bed Reactor A					Post-Fluidized Bed Reactor B				
Date	Total Cyanide (µg/L)	Free Cyanide (µg/L)	Date	Total Cyanide (µg/L)	Free Cyanide (µg/L)	Removal Efficiency, Total Cyanide (%)	Removal Efficiency, Free Cyanide (%)	Date	Total Cyanide (µg/L)	Free Cyanide (µg/L)	Removal Efficiency, Total Cyanide (%)	Removal Efficiency, Free Cyanide (%)
8/16/2017	0.84•	1.50•	8/16/2017	0.84•	1.50•	N/A	N/A	8/16/2017	—	—	—	—
10/23/2017	0.84•	1.50•	10/16/2017	0.84•	1.50•	N/A	N/A	10/23/2017	0.84•	1.50•	N/A	N/A
11/14/2017	—	—	11/14/2017	—	—	—	—	11/14/2017	—	—	—	—
12/13/2017	0.84•	1.50•	12/13/2017	0.84•	1.50•	N/A	N/A	12/13/2017	0.84•	1.50•	N/A	N/A
1/18/2018	—	—	1/18/2018	—	—	—	—	1/18/2018	—	—	—	—
2/15/2018	0.84•	1.50•	2/15/2018	0.84•	1.50•	N/A	N/A	2/15/2018	0.84•	1.50•	N/A	N/A
3/13/2018	—	—	3/13/2018	—	—	—	—	3/13/2018	—	—	—	—
4/24/2018	1.85	2.70	4/24/2018	2.01	1.39	-8.6	48.5	4/24/2018	0.84•	0.50•	54.6	81.5

— = no result
• = undetectable concentration
N/A = not applicable

Table B-7. Maximum Concentration: Total Cyanide Removal Efficiency/Free Cyanide Removal Efficiency – Membrane Bioreactor

Pre-Membrane Bioreactor			Post-Membrane Bioreactor			Removal Efficiency, Total Cyanide (%)	Removal Efficiency, Free Cyanide (%)
Date	Total Cyanide (µg/L)	Free Cyanide (µg/L)	Date	Total Cyanide (µg/L)	Free Cyanide (µg/L)		
4/13/2017	7.39	1.50•	4/13/2017	2.89	1.50•	60.9	N/A
5/19/2017	0.84•	1.50•	5/19/2017	5.58	1.50•	N/A	N/A
6/20/2017	—	—	6/20/2017	1.76	1.50•	—	—
8/16/2017*	—	—	8/16/2017*	134.00	99.90	---	---
10/23/2017	0.84•	1.50•	10/23/2017	1.75	1.50•	N/A	N/A
11/14/2017	—	—	11/14/2017	—	—	—	—
12/13/2017	2.30	1.50•	12/13/2017	0.84•	1.50•	63.4	N/A
1/18/2018	—	—	1/18/2018	—	—	—	—
2/15/2018	0.84•	1.50•	2/15/2018	0.84•	1.50•	N/A	N/A
3/13/2018	—	—	3/13/2018	—	—	—	—
4/24/2018	2.12	2.24	4/24/2018	1.96	3.45	7.3	-54.4

*Data considered suspect.

— = no result

• = undetectable concentration

N/A = not applicable

Table B-8. Minimum Concentration: Total Cyanide Removal Efficiency/Free Cyanide Removal Efficiency – Membrane Bioreactor

Pre-Membrane Bioreactor			Post-Membrane Bioreactor				
Date	Total Cyanide (µg/L)	Free Cyanide (µg/L)	Date	Total Cyanide (µg/L)	Free Cyanide (µg/L)	Removal Efficiency, Total Cyanide (%)	Removal Efficiency, Free Cyanide (%)
8/16/2017*	—	—	8/16/2017*	122.00	98.10	—	—
10/23/2017	0.84•	1.50•	10/23/2017	0.84•	1.50•	N/A	N/A
11/14/2017	—	—	11/14/2017	—	—	—	—
12/13/2017	0.84•	1.50•	12/13/2017	0.84•	1.50•	N/A	N/A
1/18/2018	—	—	1/18/2018	—	—	—	—
2/15/2018	0.84•	1.50•	2/15/2018	0.84•	1.50•	N/A	N/A
3/13/2018	—	—	3/13/2018	—	—	—	—
4/24/2018	1.43	0.95	4/24/2018	1.79	2.14	-25.6	-126.5

*Data considered suspect.

— = no result

• = undetectable concentration

N/A = not applicable

Table B-9. Maximum Concentration: Total Cyanide Removal Efficiency/Free Cyanide Removal Efficiency – Air Stripper

Pre-Air Stripper			Post-Air Stripper				
Date	Total Cyanide (µg/L)	Free Cyanide (µg/L)	Date	Total Cyanide (µg/L)	Free Cyanide (µg/L)	Removal Efficiency, Total Cyanide (%)	Removal Efficiency, Free Cyanide (%)
4/13/2017	2.89	1.50•	4/13/2017	3.02	1.50•	-4.5	N/A
5/19/2017	5.58	1.50•	5/19/2017	6.09	3.13	-9.1	N/A
6/20/2017	1.76	1.50•	6/20/2017	0.84•	1.50•	52.3	N/A
8/16/2017*	134.00	99.90	8/16/2017*	108.00	81.60	N/A	N/A
10/23/2017	1.75	1.50•	10/23/2017	0.84•	1.50•	52.0	N/A
11/14/2017	—	—	11/14/2017	—	—	—	—
12/13/2017	0.84•	1.50•	12/13/2017	1.92	1.50•	N/A	N/A
1/18/2018	—	—	1/18/2018	—	—	—	—
2/15/2018	0.84•	1.50•	2/15/2018	0.84•	1.50•	N/A	N/A
3/13/2018	—	—	3/13/2018	—	—	—	—
4/24/2018	1.96	3.45	4/24/2018	2.11	1.76	-7.7	49.0

*Data considered suspect.

— = no result

• = undetectable concentration

N/A = not applicable

Table B-10. Minimum Concentration: Total Cyanide Removal Efficiency/Free Cyanide Removal Efficiency – Air Stripper

Pre-Air Stripper			Post-Air Stripper				
Date	Total Cyanide (µg/L)	Free Cyanide (µg/L)	Date	Total Cyanide (µg/L)	Free Cyanide (µg/L)	Removal Efficiency, Total Cyanide (%)	Removal Efficiency, Free Cyanide (%)
8/16/2017*	122.00	98.10	8/16/2017*	107.00	78.60	N/A	N/A
10/23/2017	0.84•	1.50•	10/23/2017	0.84•	1.50•	N/A	N/A
11/14/2017	—	—	11/14/2017	—	—	—	—
12/13/2017	0.84•	1.50•	12/13/2017	0.84•	1.50•	N/A	N/A
1/18/2018	—	—	1/18/2018	—	—	—	—
2/15/2018	0.84•	1.50•	2/15/2018	0.84•	1.50•	N/A	N/A
3/13/2018	—	—	3/13/2018	—	—	—	—
4/24/2018	1.79	2.14	4/24/2018	0.84•	0.50•	53.1	76.6

*Data considered suspect.

— = no result

• = undetectable concentration

N/A = not applicable