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FINAL REPORT ON

Detailed Quantitative Human Health and Ecological Risk Assessment, Former Waste Disposal Middens, Bar U Ranch National Historical Site, Alberta

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REPORT



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Executive Summary

Golder Associates Ltd. (Golder) was retained by Public Works and Government Services Canada (PWGSC), on behalf of Parks Canada (PCA) to complete a Detailed Quantitative Human Health and Ecological Risk Assessment (DQHHERA) for the former waste disposal middens at the Bar U Ranch National Historic Site near Longview, Alberta (hereafter referred to as “the Site”).

The objectives of the DQHHERA were to assess potential risks to human and ecological receptors associated with the waste middens using analytical results from a recent environmental monitoring program that collected additional reference and exposure data for the Site. The middens have been capped since Meridian conducted a human health and ecological risk assessment (HHERA) in 2007. The results of the DQHHERA will be used to identify remediation or risk management measures required to mitigate any risks to human and/or ecological health for on-going management and/or closure of the Site.

Previous environmental investigations conducted at the Site identified several contaminants in soil and groundwater. To evaluate potential risks associated with contaminants at the Site, Meridian conducted an HHERA (Meridian, 2007b). The Meridian HHERA identified unacceptable risks to human and ecological receptors associated with soil and groundwater related pathways (e.g., direct contact with soil for humans, plants, soil invertebrates and wildlife, consumption of beef grazing on contaminated soil/vegetation, etc.) and identified risk management options to address these risks. Capping of the middens was selected as the risk management option for the Site and completed by AECOM (2009). Although specific capping recommendations were provided in the Meridian Risk Management Plan (RMP) (i.e., capping with geotextile membrane, clean soil of 0.5 m thickness, seeding with native plants), the waste middens were ultimately capped with less clay fill than recommended in the Meridian RMP based on the results of a subsequent geophysical survey. Golder (2017) investigated the cap’s thickness during a recent environmental monitoring program in October 2016, and results indicated that the middens cap ranged in thickness between 0 to greater than 1.2 mbgs. The thickness of the cap is considered insufficient to prevent direct contact with impacted soil by terrestrial receptors, and risks for soil related pathways remain unacceptable. As such, contaminated soils at the Site are not considered completely blocked and the conclusions/recommendations outlined in the Meridian HHERA and RMP remain applicable. The DQHHERA therefore focussed on evaluating potential risks associated with impacted groundwater, surface water and sediment at the Site and the nearby Pekisko Creek.

Based on a screening of groundwater, surface water and sediment concentrations against applicable screening guidelines and reference concentrations, no COCs were retained in groundwater, surface water or sediment.

As such, impacts in groundwater, surface water and sediment at or originating from the Site were not considered a concern for human health based on site specific considerations and the relatively low concentrations measured in environmental media.

As no COCs were retained in groundwater, surface water and sediment, aquatic receptors were considered to not be impacted in the creek. Based on site specific information including the spatial distribution of impacts, the relatively low concentrations measured in groundwater and lack of exceedances in surface water and sediment, the existing data confirms that groundwater is not impacting surface water and groundwater quality in Pekisko Creek.



In summary, potential risks to human and ecological health at the Site are considered to be acceptable with respect to groundwater, surface water and sediment exposure. With respect to soil related impacts, unacceptable risks still exist as the middens cap is not considered sufficient. Potential unacceptable risks exist for human health receptors that visit the Site and consume beef that is sourced from cattle on the Site, and ecological receptors such as plants, soil invertebrates, mammals and birds, and livestock.

Recommendations

As previously discussed, unacceptable risks associated with soil identified by the Meridian HHERA should be addressed by improving the current clay cap as per the specifications detailed in the Meridian RMP. The current cap is considered insufficient in thickness and other specifications to block and/or eliminate exposure pathways associated with contaminated soil at the Site. During the capping of the middens, all on-Site monitoring wells should be decommissioned.



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TRAV SCT



Acronyms

AEP	Alberta Environment and Parks
BCA	Bias-Corrected and Accelerated
BTEX	Benzene, toluene, ethylbenzene, xylenes
CCME	Canadian Council of Ministers of the Environment
CDWQ	Canadian Drinking Water Quality
COC	Contaminant of concern
COSEWIC	Committee on the Status of Endangered Wildlife in Canada
CSM	Conceptual Site Model
DQHHERA	Detailed Quantitative Human Health Ecological Risk Assessment
EPC	Exposure Point Concentration
ERA	Ecological Risk Assessment
FAL	Freshwater Aquatic Life
FCSAP	Federal Contaminated Sites Action Plan
FIGQG	Federal Interim Groundwater Quality Guideline
Golder	Golder Associates Ltd.
GPR	Ground penetrating radar
HHERA	Human health and ecological risk assessment
HHRA	Human Health Risk Assessment
HWS	Hot Water Soluble
HQ	Hazard Quotient
ISQG	Interim Sediment Quality Guideline
mbgs	Metres below ground surface
mbtoc	Metres below top of casing
Meridian	Meridian Environmental Inc.
NO ₃	Nitrate
PAH	Polycyclic aromatic hydrocarbon
PCA	Parks Canada
PEL	Probable Effect Level
PHC	Petroleum hydrocarbon
PPE	Personal Protective Equipment
PQRA	Preliminary Quantitative Risk Assessment
PWGSC	Public Works and Government Services Canada
RAF	Relative Absorption Factor



RBA	Relative Bioavailability Adjustment
RDL	Reportable detection limit
RfD	Reference Dose
RMM	Risk Management Measure
RMP	Risk Management Plan
ROC	Receptor of concern
SAR	Species at Risk
SARA	Species at Risk Act
SCT	Site Closure Tool
SO ₄	Sulphate
TDI	Total Daily Intake
TDS	Total dissolved solids
TRAV	Tool for Risk Assessment Validation
TRV	Toxicity reference value
UCLM	Upper Confidence Limit of the Mean
VDEQ	Virginia Department of Environmental Quality
VOC	Volatile organic compound



1.0 INTRODUCTION

Golder Associates Ltd. (Golder) was retained by Public Works and Government Services Canada (PWGSC), on behalf of Parks Canada (PCA) to complete a Detailed Quantitative Human Health and Ecological Risk Assessment (DQHHERA) for the former waste disposal middens at the Bar U Ranch National Historic Site near Longview, Alberta (hereafter referred to as “the Site”). The Site location is presented on Figure 1, a Site locality map is presented on Figure 2 and a Site plan on Figure 3 (Appendix B).

The objectives of the DQHHERA are to assess potential risks to human and ecological receptors associated with the waste middens using analytical results from a recent environmental monitoring program that collected additional reference and exposure data for the Site. The middens have been capped since a human health and ecological risk assessment (HHERA) was conducted by Meridian Environmental Inc. (Meridian) in 2007 (Meridian, 2007b). The results of the DQHHERA will inform whether further remediation or risk management measures may be required to mitigate any risks to human and/or ecological health for on-going management and/or closure of the Site via the Federal Contaminated Sites Action Plan (FCSAP) Site Closure Tool (SCT). Previous environmental investigations conducted at the Site identified several contaminants in soil and groundwater. To evaluate potential risks associated with contaminants at the Site, Meridian conducted an HHERA. The Meridian HHERA identified unacceptable risks to human and ecological receptors associated with soil and groundwater related pathways, and recommended risk management options to address these risks. A subsequent risk management plan (RMP) was completed by Meridian detailing each option (Meridian, 2007a). Capping of the middens was selected as the risk management option for the Site and completed by AECOM (2009). Although specific capping recommendations were provided in the Meridian RMP (i.e., capping with geotextile membrane, clean soil of 0.5 m thickness, seeding with native plants), the waste middens were capped with less clay fill than recommended in the Meridian RMP. Additional information on the Meridian HHERA, Meridian RMP and the capping completed at the Site by AECOM are provided in Section 2.0.

Given that Meridian (2007b) considered the thickness of the cap insufficient to prevent exposure and associated risks to human and ecological receptors that may come into contact with contaminated soil, Golder (2017) investigated the cap’s thickness during a recent environmental monitoring program in October 2016. Boreholes were advanced into the middens and soil conditions observed indicated that the middens generally consisted of a clay cap material ranging in thickness between 0 to greater than 1.2 metres below ground surface (mbgs). Given that the thickness of the cap was determined to be insufficient, Golder assumed that potential risks determined by Meridian in their HHERA (2007b) associated with the contaminated soil beneath the middens are still valid, and therefore will not be re-assessed in the DQHHERA. As such, contaminated soils are not considered completely blocked and the conclusions and recommendations from the Meridian HHERA and RMP related to requirements for the cap should be implemented at the Site. This is further discussed in Section 7.0. This DQHHERA focuses on evaluating potential risks associated with impacted groundwater, surface water and sediment at the Site and the nearby Pekisko Creek, and incorporates recent groundwater, surface water and sediment monitoring results for the Site.



2.0 BACKGROUND

The Site is located approximately 13 km south of Longview, Alberta. The Site consists of agricultural land used for cattle grazing with Pekisko Creek passing through the Site, which is used for watering livestock. The Site became a National Historic Site operated by PCA on December 31, 1991. It is currently operating as a cattle ranch and special events such as dog shows and races occasionally occur in the middens area. The middens area may continue to be a grazing area for animals such as cattle and sheep in the future.

There are two (2) waste disposal middens (coulees backfilled with waste) located in the northern portion of the Site, approximately 140 m and 210 m northwest of the creek. The West Midden is furthest to the west and measures approximately 35 m x 8 m. The East Midden is the easterly of the two middens and measures approximately 60 m x 10 m. The waste middens are roughly 100 m apart and slope towards the southeast. Waste generated by historic ranching activities at the Bar U Ranch during the over 100 years of operation (since 1881) has been placed in these coulees. The waste middens potentially contain waste oil and fuel containers, pesticide and herbicide containers, glycol, batteries, creosote-treated lumber, scrap metal, vehicles and paint containers. The Site became a National Historic Site operated by PCA on December 31, 1991. It is understood that there are water wells in the vicinity of the Site that are used for agricultural purposes. It is also understood that water from Pekisko Creek is not used as a potable water source. However, there are 22 water wells within a 1 km radius of the Site. It was previously confirmed that privately-owned groundwater wells are located within 500 m of the Site and Parks Canada drinking water wells are approximately 700 m from the middens.

A HHERA was completed by Meridian in 2007 (Meridian, 2007b) to evaluate the magnitude and significance of potential human and ecological risks resulting from contamination in the middens. Based on previous environmental assessments, contaminants of concern (COCs) identified at the Site included metals and inorganic chemicals, polycyclic aromatic hydrocarbons (PAHs), and organochlorine pesticides (i.e., chlordane and quintozine). The Meridian HHERA evaluated human receptors (i.e., general public and Site employees) and ecological receptors (i.e., plants and soil invertebrates, livestock/wildlife and aquatic life in Pekisko Creek). The results of the HHERA identified unacceptable risks associated with human and ecological receptors for direct contact pathways associated with metals (human and ecological health), PAHs (ecological health) and chlordane (ecological health) in soil. The Meridian HHERA recommended three (3) remediation/risk management approaches to block and/or eliminate the direct contact pathways, including fencing of the middens, capping of the middens and source removal. A RMP was completed by Meridian (Meridian, 2007a) with details on each of the proposed risk management options.

PCA decided that capping of the waste middens was the most appropriate risk management measure. The Meridian RMP provided specific recommendations for the capping, including laying a geotextile membrane on top of existing soils, capping with a low permeability topsoil to a thickness of at least 0.5 m, and two (2) rounds of seeding with native plant species that have relatively high water demand to reduce water infiltration through the soil.

In 2008, the middens were capped with clay fill material totaling approximately 2200 m³ (AECOM, 2009). The ground contour of the final clay cap blended in with the natural grades of the adjacent slopes, and included a positive drainage away from the waste middens. This cap was designed based on landscaping for surface water drainage and was not considered an engineered cap. The native surficial soils at the Site consist of till of even thickness. A ground penetrating radar (GPR) survey of the middens was completed by PCA in September 2015, which identified the thickness of the clay cap as approximately 0.15 m. Based on the AECOM results, the specific recommendations for capping provided by Meridian (2007a) did not appear to have been implemented.



Golder completed groundwater sampling events at the Site in December 2014 (Golder, 2015a) and July 2015 (Golder, 2016a). Groundwater impacts of nitrate (NO_3), total dissolved solids (TDS), sulphate (SO_4), chloride, cadmium, copper, iron, manganese, selenium, silver, sodium, uranium, zinc, benzo(a)pyrene and pyrene were noted. Many of these exceedances may be associated with reference conditions; however, limited reference data were available. As a result, Golder recommended the completion of an additional investigation which is hereafter referred to as the 2015 Long Term Monitoring Report (Golder, 2016a). This included the installation of a reference groundwater monitoring well, the completion of groundwater sampling at existing wells, the collection of two (2) surface water samples from Pekisko Creek (i.e., one sample hydraulically up-gradient of the waste middens [reference sample] and one sample hydraulically down-gradient of the waste middens [exposure sample], and the chemical analysis of the samples for benzene, toluene, ethylbenzene and xylenes (BTEX), petroleum hydrocarbon (PHC) Fractions F1 and F2, PAHs, volatile organic compounds (VOCs), dissolved metals, total metals, organochlorinated pesticides, and/or routine chemistry parameters. The results of the historical investigations as well as the 2015 Long Term Monitoring Report were used to evaluate potential ecological and human health risks in a Preliminary Quantitative Risk Assessment (PQRA) Update (Golder, 2016b).

The PQRA Update determined that potential risks to human and ecological health at the Site were considered to be acceptable with respect to groundwater and surface water exposure. However, the PQRA Update was based on limited data from groundwater and surface water. Sediment samples were not collected and as such, exposure related to sediment exposure was not considered. Unacceptable risks were still considered to be valid for human and ecological receptors at the Site with respect to contaminated soils beneath the middens. It was therefore recommended that unacceptable risks for soil be addressed (i.e., the clay cap be improved as per the specifications detailed in the Meridian RMP) and further environmental sampling be completed at the Site. The PQRA Update recommended that future reference samples be compared against historical reference concentrations. In the event that the new reference concentrations are higher than the historical concentrations, the conclusions provided in the PQRA Update would remain valid. If the new reference concentrations are lower than the historical concentrations, the risk assessment results would need to be re-evaluated. Similarly, if the exposure concentrations are within historical ranges, no further work is required; however, if exposure concentrations fall outside historical ranges, a re-evaluation of the risk results would be warranted.

Therefore, Golder completed an Environmental Monitoring Program in October 2016 (Golder, 2017) which consisted of confirming the thickness of the middens caps; conducting an environmental sampling program consisting of reference sampling (soil, groundwater, surface water and sediment) and exposure sampling (groundwater, surface water and sediment); and conducting an aquatic habitat assessment to confirm the quality and presence of aquatic habitat. The 2017 Environmental Monitoring Program recommended that the clay cap be improved to meet the minimum 0.5 cap thickness as per the specific recommendations provided by Meridian (2007a). Further, it was recommended that a DQHHERA be completed to evaluate potential risks to human and ecological health at the Site associated with potential groundwater, surface water and sediment impacts related the middens; the DQHHERA should incorporate the analytical results from the 2017 Environmental Monitoring Program as well as results from the aquatic habitat assessment and species at risk assessment. In the event the Site is eligible for SCT Site Closure, monitoring wells can be decommissioned.



2.1 Objectives

The objectives of the DQHHERA are as follows:

- Produce detailed, quantitative estimates of human health and ecological risks and hazards for the Site;
- Identify requirements for remediation and/or risk management and prioritize areas within the Site based on the results of the DQHHERA.

If unacceptable risks to human health and the environment warrant remedial action/risk management plan, site-specific remediation objectives (including Site Specific Target Levels) for COCs will be developed, including proposed remedial/risk management options to address unacceptable risks.

2.2 Scope of Work

The scope of work for the DQHHERA was developed in collaboration with PWGSC and PCA and was outlined in Golder's proposal entitled, "2016 Environmental Monitoring Program, Bar U Waste Middens, Waterton National Park, Longview, Alberta", dated September 23, 2016 (Golder, 2016c). As described in this proposal, upon recent discussions with PWGSC and PCA, it was decided that consideration of soil related exposure would not be addressed as the improvement of the clay cap would ultimately be recommended as a risk management option. However, reference soil sampling was recommended to use as a line of evidence, if required. Given this, unacceptable risks associated with exposure from soil on the middens is expected, and a DQHHERA will be completed to evaluate the remaining pathways on the Site related to exposure from groundwater, surface water and sediment. As such, the DQHHERA will evaluate potential risks to human and ecological health (terrestrial and aquatic) associated with impacted groundwater, surface water and sediment at the Site. A risk management plan will also be developed.

In summary, the scope of work for the DQHHERA included the following:

- Review historical reports completed for the Site as well as data collected as part of the recent environmental monitoring program. This includes analytical data obtained from soil, groundwater, surface water and sediment) as well as results from an aquatic habitat assessment completed for Pekisko Creek and the results of the field survey conducted to determine the thickness of the clay cap. Current soil data will be used as a line of evidence (if applicable) to support the DQHHERA findings;
- Incorporate applicable data into analytical datasets (Appendix A) for the DQHHERA and provide rationale for the inclusion/exclusion of data and/or pathways;
- Complete a species at risk (SAR) assessment for the Site to confirm potential SAR that may occur at the Site given that several species have been historically observed in the area;
- Conduct a DQHHERA to assess potential human and ecological risks associated with the Site. The DQHHERA should include a Problem Formulation and Risk Assessment consisting of an exposure assessment, toxicity assessment and risk characterization;
- Prepare a report documenting and detailing the methods and results of the DQHHERA as well as recommendations for further action (if required). Based on the findings, additional work and a RMP may be warranted; if warranted, a cost estimate for additional work will be included and the RMP will include risk management measures (RMMs) to mitigate exposure pathways resulting in unacceptable risks; and,
- The Site Closure Tool (SCT) and embedded tool for risk assessment validation (TRAV) will be updated based on the results of the DQHHERA.



3.0 ASSESSMENT GUIDELINES

As the Site is located within a National Park, the environmental quality of soil, groundwater, surface water and sediment at the Site falls under federal jurisdiction. The Canadian Council of Ministers of the Environment (CCME), the Federal Contaminated Sites Action Plan (FCSAP), and the Health Canada Canadian Drinking Water Quality (CDWQ) guidelines were selected to evaluate the analytical results. These generic guidelines account for potential risks to applicable receptors based on land use and soil type. The following sections outline the relevant federal guidelines and the rationale for selecting those guidelines.

3.1 Canadian Council of Ministers of the Environment

The CCME Canadian Environmental Quality Guidelines (CCME Guidelines) provide soil, surface water, and sediment quality criteria for the assessment of federal sites impacted with contaminants (CCME, current to 2017).

The CCME provide surface water guidelines for both protection of aquatic life and agricultural water uses. They include:

- CCME Canadian Water Quality Guidelines for the Protection of Freshwater Aquatic Life (FAL) (CCME, current to 2017a); and,
- CCME Canadian Water Quality Guidelines for the Protection of Agricultural (Ag) Water Uses (Irrigation and Livestock Water) (CCME, current to 2017b).

The CCME also provides sediment guidelines for the protection of freshwater or marine aquatic life. These include:

- CCME Canadian Sediment Quality Guidelines for the Protection of Aquatic Life in Freshwater (CCME, current to 2017c). These guidelines are separated into Probable Effects Levels (PELs) and Interim Sediment Quality Guidelines (ISQGs). The PELs for the protection of FAL were presented for reference only. The PELs for the protection of FAL represent the lower limit of the range of chemical concentrations that are usually or always associated with adverse biological effects (CCME, 1999). The ISQGs are generally considered more conservative and represent a threshold concentration below which adverse biological effects are expected to occur rarely. The ISQGs were used for screening, as they were considered more appropriate for a sensitive national wildlife area.

3.2 Federal Contaminated Sites Action Plan

The FCSAP Federal Interim Groundwater Quality Guidelines (FIGQGs) are to be used in connection with groundwater investigation and remediation activities at federal contaminated sites (FCSAP, 2016). This document is entitled, "Federal Contaminated Sites Action Plan Guidance Document on Federal Interim Groundwater Quality Guidelines for Federal Contaminated Sites," dated June 2016 (version 4) (FCSAP, 2016). These are risk-based guidelines developed to protect against the potential adverse effects to human health and the environment, and are developed into categories based on land use and the grain size of soil. With respect to the protection of aquatic life, the FIGQGs are based on groundwater transport to surface water at least 10 m from the contamination (FCSAP, 2016). All monitoring wells at the Site are greater than 10 m from Pekisko Creek, and as such, the FIGQGs were applicable. The FIGQGs are also protective of the inhalation of contaminants indoor air for human receptors. Table 1 FIGQGs for agricultural land use were considered the most appropriate for evaluating groundwater at the Site.



The FCSAP Guidelines follow a tiered framework, consistent with the Canadian Environmental Quality Guidelines developed by the CCME. The tiers are:

- Tier 1: direct application of the generic numerical guidelines; specifically, application of the lowest guideline for any pathway;
- Tier 2: allows for the development of site-specific remediation objectives through the consideration of site-specific conditions, by modifying (within limits) the numerical guidelines based on site-specific conditions and focusing on exposure pathways and receptors that are applicable to the site; and,
- Tier 3: use of site-specific risk assessment to develop Site-Specific Remediation Objectives.

Generally, the Tier 1 generic guidelines are considered for the preliminary identification of COCs. However, it should be noted that given the marine aquatic life pathway is considered in the derivation of the Tier 1 FIGQGs, and that the Site is not located in a marine water environment, this pathway was eliminated as a potential exposure pathway. As such, the lowest of the remaining Tier 2 FIGQGs were considered as a more appropriate Tier 1 guideline for the Site.

3.3 Canadian Drinking Water Guidelines

The guidelines for Canadian Drinking Water Quality (CDWQ Guidelines) were established by the Federal-Provincial-Territorial Committee on Drinking Water and published by Health Canada in October 2014 (Health Canada, 2014). Each guideline was established from current, published scientific research related to health effects, aesthetic effects, and operational considerations. Given that groundwater near the Site is used as a drinking water source, the Health Canada CDWQ were considered applicable.

3.4 Rationale for Selection of Criteria

The following rationale is provided to demonstrate the appropriate generic criteria selection for the Site:

- The Site is currently operating as a cattle ranch and special events occur in the middens area including dog shows and races. The middens area may continue to be a grazing area for animals such as cattle and sheep in the future. As a result, based on the land descriptions provided in the CCME and FCSAP Guidelines, the Site is classified as agricultural land use;
- The closest surface water body is Pekisko Creek which is 210 m southeast of the farthest midden and 140 m southeast of the closest midden. This water body was determined to be the closest to the Site as determined by AECOM (2009) from groundwater elevation data. Pekisko Creek is used for watering livestock;
- The native surficial soils at the Site consist of till of even thickness. Fine sediments consisting of sand, silt and clay with minor gravel beds are adjacent to Pekisko Creek. Regional surface drainage is southeast towards Pekisko Creek (AECOM, 2009); and,
- There are twenty-two water wells within a 1 km radius of the Site. It was previously confirmed that privately-owned groundwater wells are located within 500 m of the Site and Parks Canada drinking water wells are approximately 700 m from the middens (AECOM, 2009).



Based on the land use, soil grain size, and applicable exposure pathways, the following guidelines were selected to assess groundwater and surface water quality at the Site:

- Groundwater analytical results were compared to the FCSAP groundwater guidelines for fine-grained soils and agricultural land use (excluding the marine life pathway) and the CDWQ guidelines;
- Surface water analytical results were compared to the CCME water quality guidelines for the protection of freshwater aquatic life and the protection of agricultural water uses including irrigation and livestock watering; and,
- Sediment analytical results were compared to the CCME sediment quality guidelines for the protection of freshwater aquatic life (probable effect levels and interim sediment quality guidelines).

4.0 IDENTIFICATION OF CONTAMINANTS OF CONCERN

A two-tiered selection process was undertaken to identify COCs for the DQHHERA. The first step of the selection process was the Tier 1 Screening, where the maximum concentration of a parameter was compared to generic guidelines as outlined in Section 3.0. The second step of the COC selection process was the Tier 2 Screening, where parameters retained in the Tier 1 Screening process were compared to human health or ecological health component values.

The Meridian HHERA (Meridian, 2007b) evaluated potential risks to receptors at the Site using historical soil data. They reported unacceptable risks associated with human and ecological health that could be managed through the implementation of a fence around the middens, capping the middens or source removal. However, the Meridian HHERA and RMP reported specific recommendations for the middens cap related to placing geotextile membrane, thickness of the cap of 0.5 m and planting vegetation that can reduce water infiltration. Capping of the middens was selected as the risk management measure by PCA and in 2008, and a clay cap consisting of 2200 m³ of soil was placed on the middens to a thickness of 0.15 m. Golder (2017) investigated the cap's thickness during a recent environmental monitoring program in October 2016, and results indicated that the middens cap ranged in thickness between 0 to greater than 1.2 mbgs which is still considered insufficient (Figure 4, Appendix B). Given that potential risks associated with soil-related pathways were evaluated by the Meridian HHERA, Golder will not re-evaluate these pathways as part of this DQHHERA. Golder considers the soil-related risks identified by Meridian (2007a; 2007b) to be remain on-Site and valid, and that the current cap should be augmented to address the specific recommendations reported by Meridian.

For the purposes of identifying COCs in groundwater, surface water and sediment for the DQHHERA, the maximum measured concentrations collected from exposure samples were used. In addition, data from reference locations from groundwater wells (i.e., GMW18 to GMW21), surface water locations (i.e., SW15-01, SW16-01-01 to SW16-01-04, SW16-03-01 to SW16-03-03, SW16-04-01, SW16-04-02, SW16-05-01, SW16-05-02) and sediment locations (i.e., SD16-01-01 to SD16-01-04, SD16-03-01 to SD16-03-03, SD16-04-01, SD16-04-02, SD16-05-01, SD16-05-02) were also considered in identifying COCs at the Site.



The Tier 1 Screening process for COCs in groundwater, surface water and sediment is presented in the following sections. The Tier 2 Screening for human health is presented in Section 5.0 while the Tier 2 Screening for ecological health is presented in Section 6.0. All soil, groundwater, surface water and sediment data considered in the DQHHERA are summarized in Appendix A, including the summary of results from the investigation of the middens cap thickness. It should be noted that although soil data were collected from reference locations as part of the 2017 Environmental Monitoring Program, they were considered for informational purposes to support the findings of the DQHHERA and not considered for identifying potential COCs. Middens related information and soil analytical results from reference locations are presented in Tables A.1 to A.5 in Appendix A. Groundwater and surface water field monitoring results are presented in Table A.6 in Appendix A.

4.1 Contaminants of Concern in Groundwater

Groundwater data used in the DQHHERA include results from Jacques-Whitford (2004), Meridian (2007c), AECOM (2009), Golder (2015a) Golder (2016a) and Golder (2017). Groundwater data are summarized in Appendix A (Tables A.7 to A.9).

The Tier 1 Screening is presented in Tables C.1 to C.3 in Appendix C. The following approach was used in the Tier 1 Screening to identify COCs in groundwater:

- The maximum measured concentrations of analytical parameters were first compared to the lower of the FCSAP FIGQGs and Health Canada CDWQ guidelines. If a maximum measured concentration was below the selected guideline, the parameter was not retained for further consideration;
- If the maximum measured concentration of a parameter exceeded the applicable guideline value, or if no applicable guidelines were available, it was compared to the concentrations measured in the reference monitoring wells (GMW18 to GMW21). The CCME Guidance Manual for Environmental Site Characterization in Support of Environmental and Human Health Risk Assessment (CCME, 2016) allows the comparison of exposure concentrations at the Site to reference conditions considering a tolerance level or specific percentile of the reference dataset in order to identify specific locations with elevated concentrations. Health Canada (2010) also recommends screening against background concentrations, especially for parameters that have natural sources. If a contaminant has concentrations within the range of local background concentrations, it is not recommended for further consideration as a COC. A statistical method (the Wilcoxon Rank-Sum test) was used to determine if Site data fall within a typical background range (using reference monitoring wells). Substances whose concentrations in groundwater exceeded screening guidelines, but were below the typical background range, were not retained for evaluation in the risk assessment. This allowed for the elimination of parameters that are naturally occurring. A summary of the Wilcoxon Rank Sum Tests for groundwater is presented in Table C.6.
- If the maximum measured concentration only exceeded the screening guideline and did not extend beyond the reference concentration range, the parameter was considered to be related to reference levels;
- If the maximum measured reportable detection limit (RDL) exceeded the guideline value, and no other concentrations of the parameter were detectable, it was not retained for further assessment. If there were detectable concentrations and the maximum measured detectable concentration exceeded the guideline value, it was retained for further assessment;



- General parameters which were not considered a concern for human and ecological health were not retained.; and,
- If a parameter was retained based on the screening approach above, however, there was reason not to retain it for further evaluation, it was evaluated individually to determine if it should be retained for further assessment.

The Tier 1 Screening for groundwater is described in the following sections and presented in Tables C.1 to C.3 in Appendix C. Wilcoxon rank sum test results and a summary are presented in Tables C.4 to C.6 in Appendix C.

4.1.1 General Chemistry

Based on a comparison of general chemistry parameters to FCSAP FIGQGs and Health Canada CDWQ guidelines (refer to Table C.1 in Appendix C), the following exceedances were noted along with rationale for contaminant screening:

- The maximum measured concentration of nitrate (37 mg/L) at one location (MW7) exceeded the FCSAP guideline of 13 mg/L. Only two (2) concentrations of nitrate (37 mg/L measured in 2015 and 32 mg/L measured in 2016) were in exceedance of the applicable guideline. Given that the most recent sampling events identified exceedances of nitrate, it was retained as a COC for evaluation in the DQHHERA.
- The maximum measured concentration of sulphate (8390 mg/L) exceeded the FCSAP FIGQG of 100 mg/L and as such, sulphate was retained as a COC for further evaluation in the DQHHERA.
- Dissolved chloride (120 mg/L measured in 2014 and 130 mg/L measured in 2015) at one location (MW7) exceeded the FCSAP guideline of 100 mg/L. The most recent sampling event in October 2016 did not identify chloride exceedances in groundwater. Given that impacts no longer appear to exist, chloride was not retained as a COC for evaluation in the DQHHERA.

4.1.2 Metals

Metals were screened according to the method described above, as shown in Table C.2 in Appendix C. The following exceedances were noted along with rationale for contaminant screening:

- Dissolved arsenic was detected (0.0057 mg/L) at one sampling event at a single location (MW6) marginally above the FCSAP FIGQG of 0.005 mg/L. Given that the exceedance was during a single sampling event (i.e., December 2014) and a single location, it appears that the result is likely anomalous. The arsenic concentrations measured in the subsequent sampling events in July 2015 and October 2016 at the same location were below the applicable guidelines. Thus, arsenic was not retained as a COC in the DQHHERA.
- The maximum measured concentration of dissolved cadmium (0.031 mg/L) was above the FCSAP guideline of 0.000037 mg/L. Cadmium was not previously considered a COC in the 2016 PQRA Update, however given that it was measured in MW17 (new monitoring well installed on the Site) in the most recent sampling event in October 2016, it was retained for further consideration in the DQHHERA.
- The maximum concentration of dissolved copper (0.012 mg/L) was above the FCSAP guideline of 0.004 mg/L. This parameter was retained for further consideration in the DQHHERA.
- The maximum concentration of dissolved iron (3 mg/L) was above the FCSAP guideline and CDWG of 0.3 mg/L. This parameter was retained for further consideration in the DQHHERA.



- Dissolved lithium, magnesium, phosphorous, potassium, silicon, strontium, and sulphur were found at detectable concentrations, but no applicable guidelines were available. These parameters were retained for further consideration in the DQHHERA.
- The maximum concentration of dissolved manganese (3.2 mg/L) was above the CDWG of 0.05 mg/L. This parameter was retained for further consideration in the DQHHERA.
- The maximum concentration of sodium (1130 mg/L) exceeded the CDWG of 200 mg/L and was therefore retained for further consideration in the DQHHERA.
- The maximum concentration of dissolved uranium (0.1 mg/L) was above the FIGQG of 0.01 mg/L and was therefore retained for further consideration in the DQHHERA.
- The maximum concentration of dissolved zinc (0.052 mg/L) was above the FCSAP guideline of 0.03 mg/L. Exceedances of the applicable guidelines were historically identified at MW3 only in 2006 and 2015. The most recent sampling event in October 2016 did not identify any impacts of zinc in groundwater. As such, this parameter was not retained for further consideration in the DQHHERA.
- The maximum measured concentrations of selenium and silver exceed the applicable guidelines; however, these concentrations are based on historical impacts from 2004 to 2008. Concentrations from subsequent sampling events that are more representative of the current site conditions (i.e., 2014-2016) did not exceed the guidelines. As such, these parameters were not considered COCs for the DQHHERA.

It should be noted that the 2016 PQRA Update reported exceedances of selenium, silver and zinc; however, based on a comparison of the groundwater results to the more robust reference groundwater quality data, these parameters were no longer considered COCs for the DQHHERA.

The maximum measured calcium concentration in groundwater was 680 mg/L. No groundwater standards have been developed for calcium in groundwater. Calcium is an abundant element in the human body, with the majority of calcium found in bones and teeth, and helps the heart, nerves and muscles function properly (UMM, 2014). Calcium is naturally occurring and ubiquitous in the environment at detectable concentrations. It is considered non-toxic to human and ecological receptors (except when ingested in extreme quantities) and are essential elements for the growth of organisms. Given that calcium is an essential element used by both humans and ecological receptors, calcium was not retained for further evaluation in the DQHHERA.

4.1.3 Polycyclic Aromatic Hydrocarbons

PAHs were screened according to the method described above, as shown in Table C.3 in Appendix C. Based on the screening, no PAHs were retained as COCs for further evaluation.

Several PAHs (i.e., benzo(a)anthracene, benzo(a)pyrene, fluoranthene, pyrene) had detectable concentrations that exceeded their applicable guidelines, however they were based on historical impacts from 2004 to 2008. Concentrations from more recent sampling events (i.e., 2014-2016) were considered more representative of the current site conditions and did not indicate any PAH impacts in groundwater. As such, no PAHs were not retained as COCs for further evaluation in the DQHHERA.



With respect to anthracene, the maximum measured detectable concentration (0.00002 mg/L) exceeded the FIGQG; however, this impact is based on a sample analyzed in 2004 in MW1. No exceedances were measured in subsequent sampling events at this monitoring well. One other exceedance of anthracene was reported in 2014 at MW6; however, during the 2015 and 2016 sampling program, concentrations were non-detect. Given this, anthracene was not considered a COC.

4.1.4 Wilcoxon Rank Sum Tests (Groundwater Parameters)

As indicated in Section 4.1, parameters with maximum measured concentrations above selected groundwater guidelines (and parameters for which guidelines were unavailable) were statistically compared to what was considered the background range at the Site (based on reference monitoring wells). This included nitrate, sulphate, cadmium, copper, iron, lithium, magnesium, manganese, phosphorus, potassium, silicon, sodium, strontium, sulphur, and uranium. As shown in Tables C.4 to C.6, all parameters retained past the Tier 1 screening were within the background range at the Site, based on Wilcoxon rank sum tests. Concentrations below detection were assumed to be ½ the detection limits and the lower concentration of duplicate samples were removed from the dataset. As such, no chemistry parameters, metals, or PAHs in groundwater were retained as COCs for further evaluation in the HHERA.

4.1.5 Additional Results

The 2016 PQRA Update analyzed PHCs/BTEX, VOCs and pesticides in groundwater given the various contaminants that could be present in the waste middens. However, concentrations of these parameters were all below their applicable guidelines. As such, these parameter groups were not considered as part of the 2017 Environmental Monitoring Program.

4.2 Contaminants of Concern in Surface Water

Surface water data used in the DQHHERA include results from Golder (2016a) and Golder (2017). Surface water data are summarized in Appendix A (Tables A.10 to A.12). Surface water sampling locations are indicated on Figure 5 (Appendix B).

The Tier 1 Screening is presented in Tables C.7 to C.9 in Appendix C. The following approach was used in the Tier 1 Screening to identify COCs in surface water:

- The maximum measured concentrations of analytical parameters were compared to the lower of the CCME surface water guidelines for freshwater aquatic life and agricultural water uses. If a maximum measured concentration was below the selected guideline, the parameter was not retained for further consideration;
- If the maximum measured concentration of a parameter exceeded the applicable guideline value, or if applicable guidelines were unavailable, the parameter was further compared to the concentrations measured in the reference surface water locations (SW15-01, SW16-01-01 to SW16-01-04, SW16-03-01 to SW16-03-03, SW16-04-01, SW16-04-02, SW16-05-01 and SW16-05-02). Reference surface water locations were chosen upstream from where groundwater from the middens would be discharging into the creek (Figure 6, Appendix B). Groundwater elevation contours were based on a Site survey conducted by PCA in 2016. The survey was completed to the top of well cap, not the top of well casing, introducing an error on the order of 2 to 3 cm. However, given the groundwater table elevation difference over the Site (approximately 11 m), for the purpose of groundwater flow determination, the error is considered acceptable. The resulting groundwater flow direction is consistent with historical results and determined to be towards the southeast through the middens. The CCME Guidance Manual for Environmental Site Characterization in Support of Environmental



and Human Health Risk Assessment (CCME, 2016) allows the comparison of exposure concentrations at the Site to reference conditions considering a tolerance level or specific percentile of the reference dataset in order to identify specific locations with elevated concentrations. Health Canada (2010) also recommends screening against background concentrations, especially for parameters that have natural sources. If a contaminant has concentrations within the range of local background concentrations, it is not recommended for further consideration as a COC. A statistical method (the Wilcoxon Rank-Sum test) was used to determine if Site data fall within a typical background range (using reference surface water locations). Substances whose concentrations in surface water exceeded screening guidelines, but were below the typical background range, were not retained for evaluation in the risk assessment. This allowed for the elimination of parameters that are naturally occurring. A summary of the Wilcoxon Rank Sum Tests for surface water is presented in Table C.12;

- If the maximum measured concentration only exceeded the screening guideline and not the reference sample range, concentrations of the parameter were considered to be related to reference levels;
- If the maximum measured RDL exceeded the guideline value, and no other concentrations of the parameter were detectable, it was not retained for further assessment. If there were detectable concentrations and the maximum measured detectable concentration exceeded the guideline value, it was retained for further assessment;
- General parameters not considered as contaminants of concern were not retained for further consideration in the DQHERA; and,
- If a parameter was retained based on the screening approach above, however, there was reason not to retain it for further evaluation, it was evaluated individually.

4.2.1 General Chemistry

General chemistry parameters in surface water were compared to their respective CCME water quality guidelines for FAL and Ag (refer to Table C.7 in Appendix C). Based on the screening approach outlined above, nitrite and nitrate were retained as no screening guidelines were available.

4.2.2 Metals

Metals in surface water were compared to their respective CCME water quality guidelines for FAL and Ag (refer to Table C.8 in Appendix C). Based on the screening approach outlined above, barium, chromium, magnesium, potassium, silicon, sodium, strontium, and sulfur were retained for further assessment as no screening guidelines were available.

4.2.3 Polycyclic aromatic hydrocarbons

The PAHs in surface water were compared to their respective CCME water quality guidelines for FAL and Ag (refer to Table C.9 in Appendix C). Based on the screening approach outlined above, none of the parameters were retained for further assessment as all concentrations were either below applicable guidelines or below detection.

4.2.4 Wilcoxon Rank Sum Tests (Surface Water Parameters)

As indicated in Section 4.2, parameters with maximum measured concentrations above selected surface water guidelines (and parameters for which guidelines were unavailable) were statistically compared to what was considered the background range at the Site (based on surface water sampling). This included nitrite, nitrate,



barium, chromium, magnesium, potassium, silicon, sodium, strontium, and sulphur. As shown in Tables C.17 to C.20, all parameters retained past the Tier 1 screening were within the background range at the Site, based on Wilcoxon rank sum tests. Concentrations below detection were assumed to be ½ the detection limits and the lower concentration of duplicate samples were removed from the dataset. No chemistry parameters, metals, or PAHs in sediment were retained as COCs for further evaluation in the HHERA.

4.3 Contaminants of Concern in Sediment

Sediment data used in the DQHHERA include results from Golder (2017). Sediment data are summarized in Appendix A (Tables A.13 to A.15). Sediment sampling locations are indicated on Figure 5 (Appendix B).

The Tier 1 Screening is presented in Tables C.13 to C.15 in Appendix C. The following approach was used in the Tier 1 Screening to identify COCs in sediment:

- The maximum measured concentrations of analytical parameters were compared to the CCME sediment quality ISQGs. If a maximum measured concentration was below the ISQG, the parameter was not retained for further consideration;
- If the maximum measured concentration of a parameter exceeded the ISQG, or no applicable guidelines were available, it was further compared to the concentrations measured in the reference sediment locations (SD16-01-01 to SD16-01-04, SD16-03-01 to SD16-03-03, SD16-04-01, SD16-04-02, SD16-05-01 and SD16-05-02). The CCME Guidance Manual for Environmental Site Characterization in Support of Environmental and Human Health Risk Assessment (CCME, 2016) allows the comparison of exposure concentrations at the Site to reference conditions considering a tolerance level or specific percentile of the reference dataset in order to identify specific locations with elevated concentrations. Health Canada (2010) also recommends screening against background concentrations, especially for parameters that have natural sources. If a contaminant has concentrations within the range of local background concentrations, it is not recommended for further consideration as a COC. A statistical method (the Wilcoxon Rank-Sum test) was used to determine if Site data fall within a typical background range (using reference sediment locations). Substances whose concentrations in sediment exceeded screening guidelines, but were below the typical background range, were not retained for evaluation in the risk assessment. This allowed for the elimination of parameters that are naturally occurring. A summary of the Wilcoxon Rank Sum Tests for sediment is presented in Table C.19.
- If the maximum measured concentration only exceeded the screening guideline and not the reference range (based on reference sediment locations) concentrations of the parameter were considered to be related to reference levels;
- If the maximum measured RDL exceeded the guideline value, and no other concentrations of the parameter were detectable, it was not retained for further assessment.
- If there were detectable concentrations and the maximum measured detectable concentration exceeded the guideline value, it was retained for further assessment;
- General parameters typically not considered contaminants of concern were not retained for further evaluation; and,
- If a parameter was retained based on the screening approach above, however, there was reason not to retain it for further evaluation, it was evaluated individually.



4.3.1 Metals

Metals were screened according to the method described above, as shown in Table C.13 in Appendix C. The maximum measured concentration of metals parameters in sediment were below their applicable guidelines with arsenic. Concentrations of barium, beryllium, hot water soluble boron (HWS boron), cobalt, molybdenum, nickel, selenium, thallium, uranium, and vanadium did not have screening guidelines and detectable concentrations were measured.

HWS boron is not considered applicable for sediment since this parameter is applicable for soil to evaluate potential impacts to terrestrial plants and was therefore not considered a COC for further evaluation.

4.3.2 PAHs

PAHs were screened according to the method described above, as shown in Table C.14 in Appendix C. The maximum measured concentrations of PAH parameters in sediment were below their applicable guidelines with the exception of 2-methylnaphthalene and phenanthrene. As concentrations above detection were measured for benzo(b&j)fluoranthene, benzo(g,h,i)perylene, benzo(e)pyrene, and perylene and no applicable guidelines were available, these PAHs were retained for further evaluation in the DQHHERA.

4.3.3 Detailed Salinity

Detailed salinity parameters were screened according to the method described above, as shown in Table C.15 in Appendix C. Based on the screening, no detailed salinity parameters in sediment were retained as COCs. These parameters had no screening guidelines but had concentrations above detection

Calcium, magnesium, potassium and sodium are naturally occurring and ubiquitous in the environment at detectable concentrations. These parameters are integral to many proteins and enzymes for maintaining good health. Toxicological data for these parameters are not available. As such these parameters were not considered COCs for further evaluation in the DQHHERA.

Most sulphates are generated from the dissolution of minerals such as gypsum and anhydrite in groundwater and can subsequently discharge into surface water bodies and impact sediment. Sulphate is the form of sulphur that is taken up by plants in solution, and sulphur is a macronutrient that is essential for plant growth and is required for the formation of chlorophyll. Sulphate can have a laxative effect that can result in dehydration, however livestock can become acclimated to sulphate with time and symptoms can disappear (Water Research Center, 2017). As such, sulphate was not considered a COC for further evaluation.

Chloride is a major anion found in water and wastewater, however, the underlying geology and road salt application can also result in higher chloride concentrations. The chloride ion is naturally occurring and therefore increased levels in surface waters or sediment does not necessarily imply anthropogenic sources (CCME, 2011). Further, natural sources of chloride are found across Canada in areas of salt deposits (marine evaporate), including areas of Alberta (CCME, 2011). Given this, chloride was not considered a COC for further evaluation in the DQHHERA.

As such, only nitrate was retained for further evaluation in the DQHHERA.



4.3.4 Wilcoxon Rank Sum Tests (Sediment Parameters)

As indicated in Section 4.3, parameters with maximum measured concentrations above selected sediment guidelines (and parameters for which guidelines were unavailable) were statistically compared to what was considered the background range at the Site (based on sediment sampling). This included arsenic, barium, beryllium, cobalt, molybdenum, nickel, selenium, thallium, uranium, and vanadium, the PAHs benzo(b&j)fluoranthene, benzo(ghi)perylene, benzo[e]pyrene, 2-methylnaphthalene, phenanthrene, and perylene, as well as nitrate. As shown in Tables C.16 to C.19, all parameters retained past the Tier 1 screening were within the background range at the Site, based on Wilcoxon rank sum tests. Concentrations below detection were assumed to be ½ the detection limits and the lower concentration of duplicate samples were removed from the dataset. No chemistry parameters, metals, or PAHs in sediment were retained as COCs for further evaluation in the HHERA.

4.4 Summary of Contaminants of Concern for the DQHHERA

As discussed in Section 4.0, soil exceedances and associated unacceptable risks identified in the Meridian HHERA (Meridian, 2007b) still remain on the Site. As such, the DQHHERA will not re-evaluate soil-related COCs; they will be addressed in Sections 5.4 and 6.4.

No COCs were retained for further assessment in the DQHHERA based on the Tier 1 Screening and comparison to background concentrations in groundwater, surface water, and sediment. Although a risk characterization was completed as part of the 2016 PQRA Update, maximum measured concentrations have increased for several parameters based on the additional concentrations obtained in the recent environmental monitoring program (Golder, 2017). As such, a re-evaluation of the risk results for this Site was warranted.

5.0 HUMAN HEALTH RISK ASSESSMENT

The Human Health Risk Assessment (HHRA) was completed to assess risks to human receptors associated with contamination on-Site. Human receptors are not considered to spend a significant amount of time in Pekisko Creek; as such, exposure to surface water and/or sediment was not considered.

The approach taken for the risk assessment is consistent with risk assessment guidance from Health Canada (2012). The approach undertaken for the DQHHERA was quantitative in nature.

5.1 Problem Formulation

The first stage in the risk assessment framework commonly employed is the problem formulation. Within the problem formulation, a Conceptual Site Model (CSM) is developed to understand which potentially harmful contaminants (i.e., those with measured concentrations in excess of applicable guidelines are present at the Site, which human receptors may be present at the Site, and how these receptors might come in contact with the COCs. These contaminants, site users and pathways are examined in detail to identify the reasonably anticipated combinations where all three elements are present.



5.1.1 Potential Receptors

Based on the current and potential future activities at the Site and communications with PCA, human receptors considered in the HHRA include off-Site residents, ranch owners, site visitors, and construction/subsurface workers. The 2015 Long Term Monitoring Report (Golder, 2016a) indicates that there are 22 water wells located within 1 km of the Site and that Pekisko Creek is not used as a potable water source. As such, it is assumed that potable water is drawn from the groundwater aquifer for receptors living within the 1 km radius. Each of the potential receptors considered in the HHRA is described in more detail below.

5.1.1.1 Off-Site Residents

Residents of all life stages are assumed to drink potable water that is drawn from an aquifer. Groundwater at the Site is considered to be connected to this aquifer. Residents living within 1 km from the Site are assumed to drink potable water and may be exposed to COCs in groundwater originating from the Site. Adults and toddler residents were included as off-Site receptors given that these receptors are considered the most critical based on their ingestion rate to body weight ratios.

5.1.1.2 On-Site Ranch Owners/Employees

Ranch Owners/Employees would be present at the Site working at the ranch. The Ranch Owners/Employees were assumed to be adults. There are no potable water wells on-Site and although they could be exposed to contaminants via the ingestion of groundwater from potable wells off-Site, the evaluation of this pathway for residents was considered protective of these receptors. There are no buildings on-Site and therefore the inhalation of volatile COCs was not considered a complete pathway. On-Site Site Visitors

Site Visitors could be present at the Site during dog show/race events or visit the park for recreational visits. Site Visitors were assumed to be all life stages (i.e., infants, toddlers, children, teens and adults) and as discussed above, although they could be exposed to contaminants via the ingestion of groundwater from potable wells off-Site, the evaluation of this pathway for residents was considered protective of these receptors. There are also no buildings on-Site and therefore the inhalation of volatile COCs was not considered a complete pathway.

5.1.1.3 On-Site Construction/Subsurface Worker

A Construction/Subsurface Worker could be involved in construction and/or remediation activities at the Site, including trench work. The Construction/Subsurface Worker receptor would be an adult. During construction and/or remediation work, the Construction/Subsurface Worker could be exposed to volatile contaminants in a trench or to COCs in groundwater via direct contact pathways (i.e., incidental ingestion and dermal contact with groundwater). The Construction Worker/Subsurface Worker was not assumed to drink potable water from nearby off-Site wells.

5.1.1.4 Other Receptors

The receptors above are considered the critical receptors. Any other receptors that could visit the Site are considered less exposed and as such, the evaluation of potential risks for the critical receptors are protective of these receptors.

With the exception of the Construction/Subsurface Worker, receptors were assumed to be drinking potable water from wells located within a 1 km radius of the Site. The evaluation of this pathway for resident receptors was considered protective for all other human receptors.



5.1.1.5 Consideration of Soil Impacts

With respect to soil related impacts, several receptors considered above could be exposed to contaminated soil via direct contact (i.e., incidental ingestion, dermal contact, inhalation of soil particulates) as well as the consumption of beef from cattle that graze in the vicinity of the waste middens and can ingest contaminated soil. The on-Site Ranch Owner/Employees, Site Visitors and on-Site Construction/Subsurface Worker receptors can be exposed to contaminated soil via direct contact when they spend time on the Site; the same receptors with the addition of the off-Site Resident receptors could also be exposed to contaminated soil via the consumption of beef from cattle that graze on the Site.

5.1.2 Exposure Pathways

Exposure pathways are the means by which a receptor comes into contact with a COC. In the screening of COCs, numerous pathways were considered by which human receptors might come into contact with COCs at the Site. Complete and incomplete pathways are described in the following sections.

5.1.2.1 Soil Exposure Pathways

As discussed in Section 4.0 and 5.1.1, the Meridian HHERA (Meridian, 2007b) assessed potential risks associated with soil-related pathways for the Site. Soil related pathways evaluated by Meridian included direct contact with soil (i.e., incidental soil ingestion, dermal contact and soil particulate inhalation), and the consumption of beef from grazing cattle in contact with contaminated soil/vegetation. Indoor and outdoor vapour inhalation were not considered complete pathways as no buildings exist on-Site and the outdoor vapour inhalation pathway is considered a minor contributor to total exposure. In addition, produce ingestion was not considered a complete pathway as food crops or edible berries are not grown on the middens. These pathways are considered valid, however not re-evaluated as part of the DQHHERA. Associated unacceptable risks for soil-related pathways are further discussed in Section 5.4.

5.1.2.2 Groundwater Exposure Pathways

Inhalation of Air Indoors

This pathway considers the partitioning of COCs from groundwater to soil vapour and subsequent migration to indoor air. No buildings currently exist on-Site and as such, this pathway is not considered to be complete. This pathway was therefore not retained for further assessment in the HHRA.

Inhalation of Air Outdoors

This pathway considers the partitioning of COCs from groundwater to soil vapour and subsequent migration to outdoor air at the surface. It is assumed that any vapours in outdoor air would be sufficiently mixed with ambient air such that exposure associated with this pathway would be negligible. This pathway was not considered significant in the HHRA.

Inhalation of Air in a Trench

This pathway considers the partitioning of COCs from groundwater to soil vapour and subsequent migration to air within a trench. The Construction/Subsurface Worker would be present during construction or remediation activities, if required, and could be exposed to COCs via inhalation of air in the trench.



Skin Contact with Vapours in Indoor, Outdoor and Trench Air

Skin contact with vapours in indoor, outdoor and trench air are complete pathways, however exposure via this route is considered to be negligible when compared with exposure via inhalation and therefore is not evaluated in the HHRA.

Ingestion of Potable Groundwater

Receptors that drink groundwater from potable wells could be exposed to COCs originating from the Site through the ingestion pathway. There are no potable wells on the Site; as such, on-Site human receptors are not exposed to groundwater. Therefore, this pathway is considered complete in the HHRA for off-Site receptors only.

Incidental Ingestion of Groundwater

The Construction/Subsurface Worker can come into contact with contaminated groundwater through incidental ingestion during subsurface activities. There are potable wells on-Site and groundwater is deep; as such, only the Construction/Subsurface Worker could be exposed to COCs in groundwater through incidental ingestion. As such, this pathway is considered complete for this receptor.

Dermal Contact with Groundwater

This pathway considers dermal contact with groundwater through direct skin contact with groundwater. Dermal contact is considered an insignificant pathway given that the exposure is considered to be negligible when compared to ingestion of groundwater. Therefore, this pathway was not evaluated in the HHRA.

5.1.2.3 Surface Water and Sediment Exposure Pathways

Based on the Tier 1 Screening, no COCs were retained in surface water and sediment. Although receptors could visit Pekisko Creek, which is located approximately 140 to 210 m from the Site, they would not be exposed to potential COCs in surface water that are originating from the Site and as such, this pathway was not considered complete for further evaluation.

5.1.3 Contaminants of Concern for Human Health

No COCs in groundwater were identified in Section 4.1 based on generic guidelines that are intended to be protective of both human health and the environment. No COCs were retained in surface water and sediment either, and exposure to human receptors through these media would be insignificant due to the limited amount of time they would spend in the creek.

5.1.3.1 Summary of COCs for Human Health

As mentioned, no COCs were retained based on the Tier 1 screening in groundwater, surface water, or sediment. As previously discussed, metals exceedances in soil and associated unacceptable risks for human health identified in the Meridian HHERA (Meridian, 2007b) are still considered applicable for the Site. Although the DQHHERA does not re-evaluate risks related to soil-related COCs, they are discussed further in the following sections.

5.1.4 Conceptual Site Model

Taking into account the human health receptors and exposure pathways identified for the Site, a CSM was developed for the HHRA. The models summarize the potential sources, pathways of exposure and human health receptors that are considered in the HHRA. The CSM is provided in Figure 7.



5.2 Exposure Assessment

Exposure assessment involves quantifying receptor characteristics, time-activity patterns and exposure concentrations in order to estimate the dose of COCs that human receptors may receive on-Site. This is conducted for every complete COC-pathway-receptor combination identified in the CSM. The estimated dose is then combined with the toxicity information to determine risk estimates. As there were no COCs retained past the Tier 1 screening, a quantitative exposure assessment was not warranted.

5.3 Toxicity Assessment

Regulatory agencies classify contaminants based on their mode of action (i.e., threshold versus non-threshold substances). For substances exhibiting a threshold for toxicity, an acceptable level of exposure at or below which no adverse effects are anticipated is established. For non-threshold substances (including carcinogens), any level of exposure is assumed to theoretically pose a potential risk. As no COCs were retained for quantitative evaluation past the Tier 1 screening, a quantitative toxicity assessment was not considered warranted for the HHRA.

5.4 Risk Characterization: Evaluation of Human Health Risks

Risk Characterization involves integrating the exposure assessment and the toxicity assessment to determine if exposure scenarios are considered acceptable or unacceptable in terms of risk to human health. The results of the risk characterization are used to make risk management decisions for the Site. As mentioned earlier, risks were considered acceptable in groundwater, surface water, and sediment as no COCs were retained for evaluation in the HHRA.

Consideration of Soil- Related Risks

As discussed, soil related pathways were evaluated as part of the Meridian HHERA (Meridian, 2007b). Meridian reported that unacceptable risks were identified for pathways associated with direct contact with metals in soil and the consumption of the beef from grazing cattle consuming contaminated soil/vegetation. Unacceptable risks were also identified for the ingestion of groundwater pathway; however, this was re-assessed as part of the DQHHERA.

Meridian recommended several options for risk management including fencing the middens, capping the middens and removal of the impacts in the middens. For the capping option, Meridian suggested that the middens could be capped with a layer of geotextile membrane on top of existing soils, followed by at least 0.5 m of low permeability topsoil. Topsoil would then be heavily seeded with vegetation appropriate for the area including plant species with high water demand to reduce water infiltration through the soil. The capping approach was selected as the risk management option for the Site; however a cap was placed on the middens with a thickness ranging from 0 to greater than 1.2 m according to the 2017 Environmental Monitoring Report (Golder, 2017) and no geotextile membrane or specific water-demanding plant species were used (AECOM, 2009). As such, Golder considers unacceptable human health risks associated with soil identified by the Meridian HHERA are currently present at the Site and recommends that they be addressed as per the Meridian RMP recommendations for capping.



Summary of Human Health Risks

In order for risks to occur, a complete combination of COCs, potential receptors and exposure pathways must be present at the Site. Following the Tier 1 screening and statistical comparison to background concentrations, no parameters in groundwater were retained as COCs for evaluation in the HHRA. Similarly, no COCs were identified in surface water or sediment. Based on these considerations, further evaluation of potential receptors and exposure pathways associated with groundwater, surface water and sediment at the Site was not required. Risks to human health associated with measured concentrations of COCs in groundwater, surface water, and sediment at the Site are considered to be acceptable.

With respect to soil, unacceptable risks were identified at the Site for direct contact and consumption of contaminated beef pathways. To address these risks, it is recommended that the current clay cap be improved as per the specific recommendations provided in the Meridian RMP (Meridian, 2007a).

5.5 Uncertainty and Data Gaps

Numerous assumptions were made in the HHRA. The most significant assumptions and their implications on the risk conclusions are presented in the table below. In general, the assumptions are conservative and when considered together, overestimate risk. No data gaps were identified with respect to the HHRA.

Assumption	Uncertainty	Under/Over Estimate of Risk	Rationale
Exposure Concentrations			
Use of reference concentrations to screen out contaminants	Moderate	Neutral	CCME (2016) allows the comparison of exposure concentrations at the Site to reference conditions considering a tolerance level or specific percentile of the reference dataset in order to identify specific locations with elevated concentrations. Following the Tier 1 Screening, COCs with maximum measured concentrations that exceeded selected guidelines (or for which guidelines were unavailable) were compared to reference concentrations through a statistical analysis (Wilcoxon Sum Rank Test). The COCs with maximum measured concentrations that were within the background range, were not considered for further evaluation.
Exposure Assumptions			
Receptor selection	Low	Neutral	Receptors that are most likely to frequent the Site at present or in the foreseeable future were selected. Any other receptors would be less exposed. Therefore, receptor selection is likely representative and the level of uncertainty is low.
Pathways			
Pathways assessed for receptors.	Low	Neutral	Numerous pathways were considered. Those that were considered significant and complete were carried forward.



6.0 ECOLOGICAL RISK ASSESSMENT

The Ecological Risk Assessment (ERA) was completed to assess risks to ecological receptors associated with groundwater, surface water, and sediment impacts identified at the Site. The ERA was conducted in general accordance with the FCSAP ERA guidance document (FCSAP, 2012). However, the ERA was qualitative in nature.

6.1 Ecological Problem Formulation

The problem formulation is developed in an ERA to frame the issues at the Site by identifying the pertinent COCs, ecological receptors and potential exposure pathways. The receptors, exposure pathways and COCs are examined together to identify the reasonably anticipated combinations that correspond to potentially complete exposure pathways. The combinations of the environmental components that remain subsequent to the screening process form the basis of the ecological CSM and are used to focus the ERA. Where exposure scenarios can be reasonably assumed to be complete, a more detailed examination of potential risks is required.

6.1.1 Receptor Identification

A receptor of concern (ROC) is any non-human individual, species, population, community, habitat or ecosystem that may be potentially exposed to COCs on-Site. A ROC should be ecologically relevant to the Site and should have a reasonable potential to be found on-Site. According to FCSAP (2012), the selection of ROCs should take into account:

- Receptors that represent the various trophic levels, habitats, feeding guilds and environment that are most likely to receive the greatest exposure to COCs;
- Receptors that could be found on adjacent properties, but that could potentially use the Site and/or be affected by on-Site contamination;
- Receptors that are expected to be present during particular times or seasons (i.e., migratory species); and,
- Receptors that have conservation, social, economic and/or cultural importance.

6.1.1.1 Aquatic Habitat Assessment

An aquatic habitat assessment was completed for the Site (Appendix D) to support the ERA. An aquatic habitat assessment was completed by an experienced biologist to assess the habitat quality of Pekisko Creek and included observations of vegetative type and health, water levels and ability to support aquatic life, as well as the aquatic species present (or likely present) in the creek. These assessments were conducted through visual observations.

Based on existing fish and fish habitat information, Pekisko Creek is a Class C watercourse tributary of the Highwood River within the Bow River watershed. The creek is known to contain westslope cutthroat, cutthroat hybrids with rainbow trout, and rainbow trout. Bull trout, brook trout, and mountain whitefish are also known to occur in Pekisko Creek.

A 700 m reach of Pekisko Creek was surveyed and the surveyed reach was separated into distinct habitat units throughout the assessed reach (i.e., run, riffle, pool). The results of the aquatic habitat assessment indicated that aquatic habitat within Pekisko Creek was alternative riffle and run (R3), and one deep pool. The wetted width ranges from 6 m to 18.5 m wide and the bankfull width ranging between 13 m to 34 m wide. The maximum



measured depth was 0.40 m, 0.65 m and 1.5 m within riffle, R3 and P1 habitat types, respectively. Pekisko Creek has abundant unstable banks along the left downstream bank due to erosion of banks caused by high water flow. Instream cover within the watercourse was provided by large woody debris, substrate and turbulence. Overhead cover was provided by isolated areas of undercut banks. The substrate consisted of cobble, gravel and boulder in the riffle, run habitat and clay and silt in the pool habitat. There are exposed gravel bars throughout the study area. There is a 1.0 m high beaver dam extending across the channel at the upstream boundary of the surveyed area which may impede fish migration at the time of study.

The stream discharge was 0.5m³/sec., information obtained from Alberta Environment and Parks (AEP) Alberta River Basins. The field water quality measurements were: water temperature of 2.55 °C mid depth, dissolved oxygen of 11.79 mg/L, pH of 7.55 and specific conductivity of 242 µ/cm. Based on these measurements and the above observations, the aquatic habitat was considered to be in good quality.

Although Pekisko Creek is considered to provide habitat to aquatic biota, no fish were observed during the field survey.

6.1.1.2 Species at Risk Assessment

A desktop SAR screening assessment was conducted as part of the DQHHERA to determine if federally or provincially listed species have the potential to be located on the Site. The potential for SAR to occur on the Site was assessed based on recent and historical records for species of concern. Information reviewed as part of the SAR assessment included species range information, known records, interpretation of aerial imagery and site photos, historic land use practices, and the preferred habitat requirements of these species. Species with ranges overlapping the Study Area, or recent occurrence records in the vicinity, were screened by comparing their habitat requirements to apparent habitat conditions on the Site.

The SAR assessment is provided in Appendix E. Potential for the species to occur on the Site was determined through a probability of occurrence. A ranking of low indicates no suitable habitat availability for that species on the Site and no specimens identified. Moderate probability indicates a higher potential for the species to occur, as suitable habitat appeared to be present on the Site, but no occurrence of the species has been recorded on the Site. High potential indicates a known species record on the Site (including during field surveys or background data review) and good quality habitat is present on the Site.

The results indicated that the following nine (9) SAR have a high or moderate likelihood to occur at the Site:

- Monarch (*Danaus plexippus*);
- Northern leopard frog (*Lithobates pipiens*);
- Baird's sparrow (*Ammodramus bairdii*);
- Peregrine falcon (*Falco peregrinus*);
- Short-eared owl (*Asio flammeus*);
- Common nighthawk (*Chordeiles minor*);
- Ferruginous hawk (*Buteo regalis*);
- West slope cutthroat trout (*Oncorhynchus clarkii lewisi*); and,
- Little brown myotis (*Myotis lucifugus*).



Four (4) additional species that have been assessed as SAR by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC), but are not yet designated under the Species at Risk Act (SARA), have a moderate or high likelihood to occur in the Study Area. The grizzly bear (*Ursus arctos*) was assessed as special concern by COSEWIC. The barn swallow (*Hirundo rustica*), bank swallow (*Riparia riparia*), and bull trout (*Salvelinus confluentus*) were assessed as threatened by COSEWIC.

The above 13 species are considered terrestrial receptors with the exception of the west slope cutthroat trout and the bull trout, which are considered aquatic receptors.

It should be noted that AEP identified several fish species to be SAR (i.e., bull trout, cutthroat trout, mountain whitefish and rainbow trout) based on an August 2015 SAR screening (Appendix E); however, given the most recent SAR assessment, the bull trout was considered threatened and not yet assessed as a SAR by COSEWIC. Further, based on previous communication with PCA, the following SAR were identified to be associated with the Site and surrounding area: little brown bat, barn swallow, common nighthawk, sharp-tailed grouse. Again, based on the most recent SAR assessment, only the little brown myotis and common nighthawk were considered to be SAR for the Site; the barn swallow is currently assessed as threatened under COSEWIC.

As such, the 9 SAR identified above will be considered in the ERA.

6.1.1.3 Receptors of Concern

ROCs are selected based on the ecological conditions as well as consideration of the nature of the COCs. Receptors of concern evaluated in the ERA include the following:

- Benthic and pelagic invertebrates;
- Aquatic plants;
- Fish species;
- Plants and soil invertebrates;
- Wildlife (mammals and birds) and livestock (e.g., cattle); and,
- Amphibians and reptiles.

The species that have intrinsic ecological significance include terrestrial plants and soil invertebrates. As primary producers, plants play a critical role within any ecosystem by sustaining most other life forms on Earth. Therefore, terrestrial plants and soil invertebrates were selected as ROCs for the Site.

Mammals and birds were also included as ROCs for the Site. The middens on the Site are covered in grassland. The mix of plant communities is considered habitat for a wide variety of wildlife species. Wildlife species are also expected to spend time at Pekisko Creek, which is a moderately flowing stream, with a variety of riffles, runs and pools. Wildlife can use the creek as a water source. Several wildlife (i.e., mammals and birds) have been spotted at and near the Site by PCA, including the following: white tail deer, mule deer, Canada geese, ducks, herons, hawks, killdeers, meadowlarks, bald eagles, Richardson's ground squirrels, thirteen-lined ground squirrels, beavers, coyotes, moose, elk, swallows, bats, wolves, grizzly bears, black bears and cougars. Garter snakes and frogs were also observed on/near the Site. Further, the Site is located within the provincially designated prairie falcon, golden eagle and bald eagle sensitive nesting range. Bald eagles regularly use the valley and congregate on the Site.



Amphibians and reptiles will be qualitatively evaluated in this assessment as there is generally a lack of data regarding exposure and effects of contaminants which presents a challenge for assessing the risks posed by contaminants to these animals.

Aquatic biota that are considered ROCs for the Site include benthic and pelagic invertebrates, aquatic vegetation and fish species.

SAR are afforded more protection due to the regulatory requirements to protect individual organisms of a listed species compared with the protection of populations for common species. The eight (8) terrestrial SAR identified above were considered ROCs for the Site.

6.1.1.4 Protection Goals and Acceptable Effect Levels

The protection goals for the Site are as follows:

- Maintenance of healthy ROC communities/populations; and
- Protection of SAR at an individual level.

In order to meet these protection goals, there should be no significant measurable effects on community dynamics or structure and function. In the case of SAR species, there should be no adverse individual level effects.

6.1.2 Exposure Pathway Identification

Exposure pathways are the means by which receptors come into contact with COCs. In order for an exposure pathway to exist, a contaminant source, a release mechanism, transport media, and a receptor must be present. Inoperable and/or negligible pathways were not evaluated in the ERA.

No COCs were retained based on the screening of parameters in groundwater, surface water and sediment; the exclusion of related pathways is discussed below. Given this, aquatic ROCs were no longer considered applicable for evaluation in the ERA. As such, it can be concluded that potential risks to receptors associated with exposure to groundwater (e.g., plants, soil invertebrates, aquatic biota) as well as surface water and sediment (e.g., aquatic biota) are considered to be acceptable.

As previously discussed, the Meridian HHERA (Meridian, 2007b) assessed potential ecological risks associated with soil-related pathways for the Site. Soil related pathways evaluated by Meridian included direct contact with soil for plants, soil invertebrates, wildlife and livestock. The Meridian HHERA stated that amphibians in and near Pekisko Creek are not expected to be significantly affected by the contamination in the middens. Soil related pathways are considered valid, however not re-evaluated as part of the DQHHERA. Associated unacceptable risks for soil-related pathways are further discussed in Section 6.4.

Inoperable and/or negligible pathways were not evaluated in the ERA. Rationale for the inclusion or exclusion of potential pathways for each receptor group is provided in the following table.



Table 1: Exposure Pathway Selection

Exposure Pathway	Relevant to Site (Y/N)	Rationale
Soil		
Direct Contact with Soil	Y	Terrestrial plants and soil invertebrates can be exposed to contaminated soil via direct contact.
Stem and Foliar Uptake of Volatiles	N	Terrestrial plants may be exposed to volatile COCs via stem and foliar uptake of ambient air; however, it is assumed that vapours in outdoor air would rapidly mix with ambient air and be diluted such that risks associated with this pathway would be negligible. Furthermore, exposure information associated with this pathway is subject to a high degree of uncertainty.
Dermal Contact with Soil	N	Wildlife (mammals and birds) can be exposed to soil via dermal contact, however, exposure via this pathway is expected to be negligible as the presence of feathers of birds and fur on mammals limits dermal contact with contaminated soil (US EPA, 2005; Sample and Suter, 1994). Furthermore, the data necessary to evaluate dermal contact exposure is often lacking (US EPA, 1993; Sample and Suter, 1994), or if available, based on studies in which the chemical is applied directly to the skin by shaving the fur from laboratory rodents (US EPA, 2005), a type of exposure that would not occur in the natural environment.
Inhalation of vapours	N	Wildlife (mammals and birds) can be exposed to volatile contaminants in soil via inhalation of vapours. COCs in soil retained in the Meridian HHERA included metals, total PAHs and chlordane. Although PAHs are volatile or semi-volatile (depending on the PAH), exposure via this pathway is considered to be negligible. This is because vapours would be rapidly mixed with ambient air and diluted such that concentrations would not pose unacceptable risk to mammals and birds. Exclusion of this pathway is also consistent with the approach used by CCME (2006) in deriving soil quality guidelines.
Soil Ingestion	Y	Wildlife (mammals and birds) and livestock can be exposed to contaminated soil via ingestion of soil.
Consumption of Prey	Y	Wildlife (mammals and birds) can be exposed to contaminated soil through food chain transfer.



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Exposure Pathway	Relevant to Site (Y/N)	Rationale
Groundwater		
Root Uptake and Direct Contact	N	Terrestrial plants and soil invertebrates could be exposed to contaminated shallow groundwater. However, soil invertebrates generally try to avoid the saturated zone and reside in unsaturated shallow soils. Groundwater at the Site ranges from 1.79 to 4.66 mbtoc, which is considered too deep for exposure by these receptors. Further, no COCs in groundwater were retained for the ERA.
Groundwater Exposure/ Consumption	N	Groundwater is not accessible to terrestrial wildlife or livestock for consumption; however, livestock may be exposed to contaminated groundwater as groundwater may be used as a source for irrigation and livestock watering. However, no COCs in groundwater were retained for the ERA.
Discharge to Surface Water	N	COCs in groundwater have the potential to be released into Pekisko Creek where aquatic receptors could be exposed to these COCs. Wildlife such as mammals and birds can also consume surface water as a source of drinking water. However, no COCs in surface water were retained.
Surface Water		
Surface Water Exposure	N	Aquatic receptors could be exposed to COCs in groundwater migrating to surface water through direct contact, ingestion and gill/plant uptake. However, no COCs were retained in surface water.
Food Consumption	N	Aquatic mammals and birds can be exposed to COCs present in food items if chemical uptake into tissues occurs. However, no COCs in surface water were retained.
Sediment		
Sediment Exposure	N	Aquatic receptors could be exposed to COCs in groundwater migrating to sediment through direct contact and ingestion. However, no COCs were retained in sediment.
Food Consumption	N	Aquatic mammals and birds can be exposed to COCs present in food items if chemical uptake into tissues occurs. However, no COCs in sediment were retained.



6.1.3 Contaminants of Concern for Ecological Health

No COCs in groundwater were identified in Section 4.1 based on generic guidelines that are intended to be protective of both human health and the environment. No COCs were retained in surface water and sediment either and as such, no impacts from the middens were considered to exist in Pekisko Creek.

The Meridian HHERA (Meridian, 2007b) considered soil-related pathways including the direct contact with contaminated soil pathway for plants, soil invertebrates, wildlife and livestock associated with metals, PAH and chlordane as COCs identified in soil. This pathway and associated unacceptable risks to ecological receptors identified by Meridian are considered valid; however, they are not re-assessed in this DQHHERA. As such, only ecological pathways associated with groundwater are evaluated in the ERA.

6.1.3.1 COCs in Groundwater

Based on the results of the Tier 1 screening, no parameters were retained as COCs in groundwater.

6.1.3.2 COCs in Surface Water and Sediment

Based on the results of the Tier 1 screening, no parameters were retained as COCs in surface water and sediment.

6.1.3.3 Summary of COCs for Ecological Health

Based on the Tier 2 Screening for ecological health, no COCs were retained in groundwater, surface water and sediment.

As previously discussed, metals, PAH and chlordane in soil exceedances and associated unacceptable risks for ecological health identified in the Meridian HHERA (Meridian, 2007b) still remain on the Site. Although the DQHHERA will not re-evaluate risks associated with soil-related COCs, they are discussed in the following sections. Some of these COCs may be persistent and bioaccumulative in ecosystem.

6.1.4 Conceptual Site Model

Exposure pathways are the means by which receptors come into contact with COCs. In order for an exposure pathway to exist, a contaminant source, a release mechanism, transport media, and a receptor must be present. The terrestrial and aquatic CSMs are provided in Figure 8a and 8b, respectively.

6.2 Exposure Assessment

The exposure assessment estimates the amount of COC to which each of the ecological receptors is exposed. No COCs were retained in groundwater, surface water or sediment; as such, this section was not evaluated relevant for the risk assessment. However, metals, PAH and chlordane COCs in soil retained as part of the Meridian HHERA (2007b) were still considered applicable for the Site and are evaluated further in Section 6.4.

6.3 Toxicity Assessment

The effects assessment characterizes potential effects associated with COCs. It provides the basis for evaluating with level of exposure may adversely affect the health of receptors. This involves identification of the potential toxic effects of COCs and determining the concentrations to which receptors can be exposed without adverse effects. Toxicity benchmark values are used as thresholds for comparison with exposure point concentrations (for plants) during risk characterization.



No COCs were retained in groundwater, surface water or sediment; as such, this section was not evaluated. However, metals, PAH and chlordane COCs in soil retained as part of the Meridian HHERA (2007b) were still considered applicable for the Site and are evaluated further in Section 6.4.

6.4 Risk Characterization: Evaluation of Ecological Risks

Risk Characterization involves integrating the exposure assessment and the effects assessment to determine if exposure scenarios are considered acceptable or unacceptable in terms of risk to ecological health. The results of the risk characterization are used to make risk management decisions for the Site. The results of the risk characterization are used to make risk management decisions for the Site.

6.4.1 Risk Results

No COCs were retained in groundwater, surface water or sediment for ecological receptors; as such, a quantitative risk estimates were not relevant for the Site. Potential risks associated with exposure to groundwater, surface water and sediment were therefore considered to be acceptable for ecological receptors at the Site.

Metals, PAH and chlordane COCs in soil retained as part of the Meridian HHERA (2007b) were still considered applicable for the Site and are evaluated further below.

Consideration of Soil-Related Risks

As discussed, soil related pathways were evaluated as part of the Meridian HHERA (Meridian, 2007b). Meridian reported that unacceptable risks were identified for pathways associated with direct contact with soil for plants and soil invertebrates and wildlife. Acceptable risks were identified for groundwater and/or surface water-related pathways associated with the Site and Pekisko Creek. However, given that additional groundwater, surface water and sediment results are available for the Site since the Meridian HHERA, evaluation of potential risks associated with these media were re-evaluated as part of the DQHHERA.

With respect to soil-related risks, Meridian recommended several options for risk management including fencing the middens, capping the middens and removal of the impacts in the middens. For the capping option, Meridian suggested that the middens could be capped with a layer of geotextile membrane on top of existing soils, followed by at least 0.5 m of low permeability topsoil. Topsoil would then be heavily seeded with vegetation appropriate for the area including plant species with high water demand to reduce water infiltration through the soil. The capping approach was selected as the risk management option for the Site; however a cap was placed on the middens with a thickness of 0.15 m and no geotextile membrane or specific water-demanding plant species were used (AECOM, 2009). Golder (2017) investigated the cap's thickness during a recent environmental monitoring program in October 2016. Boreholes were advanced into the middens and soil conditions observed indicated that the middens generally consisted of a clay cap material ranging in thickness between 0 to greater than 1.2 metres below ground surface (mbgs). Given that the thickness of the cap was determined to be insufficient, Golder considers that potential risks determined by Meridian in their HHERA (2007b) associated with the contaminated soil beneath the middens remain valid. As such, contaminated soils are not considered adequately blocked and the conclusions and recommendations from the Meridian HHERA and RMP related to requirements for the cap should be implemented at the Site.



Consideration of 2016 PQRA Update Results

It should be noted that although no COCs were identified in groundwater, surface water and sediment in the current DQHHERA, groundwater COCs were previously identified for the Site in the 2016 PQRA Update. Specifically, general chemistry parameters, metals and PAHs in groundwater (i.e., nitrate, chloride, copper, iron, selenium, silver, zinc, anthracene, benzo(a)anthracene, benzo(a)pyrene, fluoranthene and pyrene) were identified above the reference+20% concentration and FIGQG FWAL screening guideline. Concentrations from only one (1) reference groundwater well (i.e., GMW18) were considered in the evaluation. Further, concentrations from only one (1) surface water reference location and one (1) surface water exposure location were available, which was considered insufficient to accurately evaluate whether these groundwater COCs were ultimately discharging into Pekisko Creek and impacting aquatic receptors. No COCs in surface water were retained in the 2016 PQRA Update. This was expected as considerable dilution of groundwater concentrations would occur immediately upon release into Pekisko Creek. Based on the 2016 PQRA Update, potential risks to aquatic receptors were considered to be acceptable.

The sampling completed in support of the DQHHERA provided numerous results for groundwater, surface water and sediment, to further characterize the environmental quality of these media at the Site. Based on these data, concentration ranges of the reference samples and exposure samples were updated, and in several cases, COCs previously identified were no longer considered COCs for the DQHHERA.

Summary of Ecological Health Risks

In order for risks to occur, a complete combination of COCs, potential receptors and exposure pathways must be present at the Site. Following the Tier 1 screening, no COCs were identified in groundwater, surface water, and sediment. Based on these considerations, further evaluation of potential receptors and exposure pathways is not required. Risks to ecological health associated with measured concentrations of COCs in groundwater, surface water and sediment at the Site are considered to be acceptable.

With respect to soil, unacceptable risks were identified at the Site for direct contact for plants, soil invertebrates and wildlife. To address these risks, it is recommended that the current clay cap be improved as per the specific recommendations provided in the Meridian RMP (Meridian, 2007a).

6.5 Uncertainty and Data Gaps

Numerous assumptions were made in the ERA. The most significant assumptions and their implications on the risk conclusions are presented in the table below. In general, the assumptions are conservative and when considered together, overestimate risk. Therefore, although there is uncertainty associated with the assumptions, the uncertainty does not change the conclusions of the risk assessment. No data gaps were identified with respect to the ERA.



Source of Uncertainty	Level of Uncertainty	Over-/Under-estimate of Risk	Rationale
Exposure Concentrations			
Use of reference concentrations to screen out contaminants	Moderate	Neutral	CCME (2016) allows the comparison of exposure concentrations at the Site to reference conditions considering a tolerance level or specific percentile of the reference dataset in order to identify specific locations with elevated concentrations. Following the Tier 1 Screening, COCs with maximum measured concentrations that exceeded selected guidelines (or for which guidelines were unavailable) were compared to reference concentrations through a statistical analysis (Wilcoxon Sum Rank Test). The COCs with maximum measured concentrations that were within the background range, were not considered for further evaluation.
Exposure Assumptions			
Receptor selection	Low	Neutral	Receptors that are most likely to frequent the Site were selected, including those observed by PCA personnel and/or identified as species at risk by the SAR assessment (Appendix E). The ROCs selected in the ERA are considered protective of the species observed by PCA. Given that only soil COCs were retained for ecological health based on the Meridian HHERA (2007b), only terrestrial receptors were considered in the ERA. No COCs were retained for ecological health in groundwater, surface water and sediment; as such, aquatic receptors were not considered applicable. Receptor selection is likely representative and the level of uncertainty is low.
Pathways			
Pathways assessed for receptors.	Low	Neutral	Numerous pathways were considered for terrestrial and aquatic receptors. Those that were considered significant and complete were carried forward.



7.0 RISK MANAGEMENT PLAN

Based on the results of the DQHHERA, potential risks to human and ecological receptors exposed to groundwater, surface water and sediment on the Site were considered to be acceptable.

Potential risks associated with soil exposure for human and ecological receptors were considered to be unacceptable, as per the findings of the Meridian HHERA. As such, to mitigate these risks, the RMMs associated with improving the middens cap are recommended and discussed below.

Improvement of Middens Clay Cap

To mitigate soil-related risks, the middens should be capped. The cap should consist of geotextile membrane and low-permeability soil with a thickness of approximately 0.5 m over the middens. It was indicated by Meridian that the 0.5 m thickness would not necessarily cover all the debris. In areas where large debris is noted and observed (e.g., vehicles, barrels, etc.), they should be removed and disposed of appropriately.

The geotextile membrane consisting of a 20-millimetre PVC liner should be installed flat areas of the middens to reduce the potential for upwards migration of soil contaminants due to capillary rise, and reduce the potential for plant roots to penetrate into the contaminated soils (Meridian, 2007a).

The soil placed onto of the middens should be clean and blended with the local topography. The soils should be capped with topsoil and seeded with native plant species.

Dust that is generated during construction activities should be mitigated by the use of personal protective equipment (PPE) such as a respiratory mask.

Decommissioning of on-Site Monitoring Wells

On-Site monitoring wells should be decommissioned prior to improving the middens cap as several wells are located on the middens and will be damaged in the improvement process. Once the middens have been sufficiently capped, potential risks to human health and the environment for all media on the Site would be considered acceptable. As such, the remaining monitoring wells should also be decommissioned. As per CCME guidance (2016), if the screen and filter pack intervals of the well do not cross communicate between separate groundwater flow zones, then the casing should be removed and the borehole should be backfilled from its base with a low permeability grout. If the borehole collapses after the casing is removed, or if the screens do cross communicate between flow zones, the well should be re-drilled and grouted. If an alternative to well removal is required, the well can be sealed by injecting grout into the well under pressure to ensure grout goes through the well screen and into the filter pack. If the well is damaged below grade, the well should be drilled out and the borehole should be grouted.

Prevention of Well Damage and Exposure to Cattle

A permanent fence could be constructed around the debris in the middens to prevent human and ecological receptors from accessing the middens area. The fence would prevent cattle from grazing in the middens area and would subsequently prevent consumption of beef sourced from contaminated cattle. The fence will also prevent damage of monitoring wells by cattle that graze on and near the middens. The fence should be maintained.



8.0 CONCLUSIONS/RECOMMENDATIONS

Golder was retained by PWGSC, on behalf of PCA to complete a DQHHERA for the former waste disposal middens at the Bar U Ranch National Historic Site near Longview, Alberta.

The objectives of the DQHHERA were to assess potential risks to human and ecological receptors associated with the waste middens using analytical results from a recent environmental monitoring program that collected additional reference and exposure data for the Site. The middens have been capped since Meridian conducted an HHERA in 2007. The results of the DQHHERA were able to support potential future remediation or risk management measures may be required to mitigate any risks to human and/or ecological health for on-going management and/or closure of the Site.

Previous environmental investigations conducted at the Site identified several contaminants in soil and groundwater. To evaluate potential risks associated with contaminants at the Site, Meridian conducted an HHERA (Meridian, 2007b). The Meridian HHERA identified several unacceptable risks to human and ecological receptors associated with soil and groundwater related pathways (e.g., direct contact with soil for humans, plants, soil invertebrates and wildlife, consumption of beef grazing on contaminated soil/vegetation, etc.) and recommended risk management options to address these risks. Capping of the middens was selected as the risk management option for the Site and completed by AECOM (2009). Although specific capping recommendations were provided in the Meridian RMP (i.e., capping with geotextile membrane, clean soil of 0.5 m thickness, seeding with native plants), the waste middens were ultimately capped with less clay fill than recommended in the Meridian RMP based on the results of a subsequent geophysical survey. Golder (2017) investigated the cap's thickness during a recent environmental monitoring program in October 2016, and results indicated that the middens cap ranged in thickness between 0 to more than 1.2 mbgs. The thickness of the cap is considered insufficient to prevent soil related exposure and therefore associated risks to human and ecological receptors that may come into contact with contaminated soil as identified in the Meridian HHERA still remain. These potential risks associated with soil were considered to be present at the Site and were not re-assessed in the DQHHERA. As such, contaminated soils at the Site are not considered completely blocked and the conclusions/recommendations in the Meridian HHERA and RMP are considered applicable. The DQHHERA therefore focussed on evaluating potential risks associated with impacted groundwater, surface water and sediment at the Site and the nearby Pekisko Creek.

Based on a screening of groundwater, surface water and sediment concentrations against applicable screening guidelines and reference concentrations, no COCs were retained in groundwater, surface water or sediment.

As such, impacts in groundwater, surface water and sediment at or originating from the Site were not considered a concern for human health based on site specific considerations and the relatively low concentrations measured in environmental media.

As no COCs were retained in groundwater, surface water and sediment, aquatic receptors were not considered to be impacted in the creek. Based on site specific information including the spatial distribution of impacts, the relatively low concentrations measured in groundwater and lack of exceedances in surface water and sediment, the existing data confirms that groundwater is not impacting surface water and groundwater quality in Pekisko Creek.



In summary, potential risks to human and ecological health at the Site are considered to be acceptable with respect to groundwater, surface water and sediment exposure. With respect to soil related impacts, unacceptable risks still exist as the middens cap currently in place is not considered sufficient. Potential unacceptable risks exist for human health receptors that visit the Site and consume beef that is sourced from cattle on the Site, and ecological receptors such as plants, soil invertebrates, mammals and birds, and livestock.

Recommendations

As previously discussed, unacceptable risks associated with soil identified by the Meridian HHERA should be addressed by improving the current clay cap as per the specifications detailed in the Meridian RMP. The current cap is considered insufficient in thickness and other specifications to block and/or eliminate exposure pathways associated with contaminated soil at the Site. During the capping of the middens, all on-Site monitoring wells should be decommissioned.

The TRAV and SCT is presented in Appendix F.

9.0 LIMITATIONS

This report was prepared for the exclusive use of Public Works and Government Services Canada and Parks Canada. The report, which specifically includes all tables, figures, and appendices, is based on data and information collected during the Site activities conducted by Golder Associates Ltd. and is based solely on the conditions of the property at the time of the Site field program and data obtained by Golder Associates Ltd. as described in this report.

The services performed as described in this report were conducted in a manner consistent with that level of care and skill normally exercised by other members of the engineering and science professions currently practicing under similar conditions.

Any use which a third party makes of this report, or any reliance on, or decisions to be made based on it, are the responsibilities of such third parties. Golder Associates Ltd. accepts no responsibility for damages, if any, suffered by any third party as a result of decisions made or actions based on this report.

The content of this report is based on information collected during our assessment, our present understanding of the Site conditions, and our professional judgement in light of such information at the time of this report. This report provides a professional opinion and therefore no warranty is either expressed, implied, or made as to the conclusions, advice and recommendations offered in this report. This report does not provide a legal opinion regarding compliance with applicable laws. With respect to regulatory compliance issues, it should be noted that regulatory statutes and the interpretation of regulatory statutes are subject to change. The findings and conclusions of this report are valid only as of the date of this report. If new information is discovered in future work, including excavations, borings, or other studies, Golder Associates Ltd. should be requested to re-evaluate the conclusions of this report, and to provide amendments as required.



10.0 CLOSURE

We trust the above meets your present requirements. If you have any questions or require additional details, please contact the undersigned.

Sincerely,

GOLDER ASSOCIATES LTD.

For

Tessa Roselli, M.Sc.
Environmental Risk Assessor

Michael Z'Graggen, MRM
Associate, Senior Risk Assessor

TR/MZ/JM/sg/hw

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APPENDIX A

Analytical Results

Table A.1
Summary of Middens Clay Cap Thickness
Bar U Ranch National Historic Site, Alberta
Public Works and Government Services Canada

ID	Date	Waste or Debris Observed	Stratigraphic Changes or Observations	Estimated Clay Cap Thickness	GPS Coordinates (11U)	
					Northing	Easting
MD16-01	25-Oct-16	--	change from clay to silty clay at 0.89 m	0.9	5,589,523	695,303
MD16-02	25-Oct-16	bone fragments at 0.9 m	silty clay from beneath topsoil to end of borehole	0.0	5,589,534	695,292
MD16-03	25-Oct-16	--	firm at 0.9 m	0.9	5,589,535	695,280
MD16-04	25-Oct-16	--	clay to end of borehole	>1.1	5,589,544	695,272
MD16-05	25-Oct-16	barbed wire at 1.1 m; aluminum debris at 1.5 m	change from clay to silty clay at 1.14 m	1.1	5,589,550	695,263
MD16-06	25-Oct-16	wood, glass, bone, ceramic and brick from 0.5 to 1.1 m	clay to end of borehole	0.5	5,589,557	695,253
MD16-07	25-Oct-16	blue plastic debris at 0.7 m	silty clay from beneath topsoil to end of borehole	0.0	5,589,554	695,243
MD16-08	25-Oct-16	bone fragments at 0.9 m	change from clay to silty clay at 0.64 m	0.9	5,589,561	695,230
MD16-09	25-Oct-16	metal debris/barbed wire at 1.1 m	fine sand pocket at 1.0 m	1.1	5,589,567	695,243
MD16-10	25-Oct-16	--	clay to end of borehole	>1.1	5,589,618	695,375
MD16-11	25-Oct-16	beer can at 0.5 m	clay to end of borehole	0.5	5,589,624	695,390
MD16-12	25-Oct-16	--	clay to end of borehole	>1.1	5,589,616	695,400
MD16-13	25-Oct-16	--	clay to end of borehole	>1.1	5,589,624	695,418
MD16-14	25-Oct-16	--	clay to end of borehole	>1.2	5,589,617	695,427
MD16-15	25-Oct-16	--	change from clay to silty clay at 0.88 m	0.9	5,589,615	695,439
MD16-16	25-Oct-16	--	change from clay to silty clay at 0.94 m	0.9	5,589,618	695,452
MD16-17	25-Oct-16	--	silty clay from beneath topsoil to end of borehole	0.0	5,589,609	695,458
MD16-18	25-Oct-16	--	change from clay to silty clay at 0.84 m	0.8	5,589,622	695,468
MD16-19	25-Oct-16	piece of unprocessed natural wood at 0.2 m	change from clay to silty clay at 0.89 m	0.2	5,589,610	695,468
MD16-20	25-Oct-16	--	change from clay to silty clay at 0.15 m	0.2	5,589,599	695,468

Notes:

m bgs - metres below top of casing

m - metres

-- none observed

Table should be read in conjunction with accompanying report.

Table A.2
Summary of Soil Analytical Results - Polycyclic Aromatic Hydrocarbons
Bar U Ranch National Historic Site, Alberta
Public Works and Government Services Canada

Reference or Exposure Location			CCME Environmental Health Guidelines ^{(a)(b)}	Reference											
Sample Identification				GMW18-7	GMW19-1	GMW19-2	GMW19-9	GMW20-1	GMW20-2	GMW21-1	GMW21-2	GMW21-3	GBH22-1	GBH22-2	GBH22-3
Sample Depth (m bgs)				4.5 - 5.25	0.46-0.76	1.83-1.98	0.46-0.76	0.3-0.61	1.22-1.37	0.0-0.3	1.22-1.37	1.83-1.98	0-0.3	1.22-1.37	1.83-1.98
Headspace Combustible Vapour (ppm)				85	0	0	0	0	0	0	0	0	0	0	0
Sample Collection Date				20-Nov-15	24-Oct-16	25-Oct-16	25-Oct-16	25-Oct-16							
Parameter	Units	2016 RDL													
Acenaphthene	mg/kg	0.005	0.28	< 0.0050	< 0.0050	< 0.0050	< 0.0050	< 0.0050	< 0.0050	< 0.0050	< 0.0050	< 0.0050	< 0.0050	< 0.0050	< 0.0050
Acenaphthylene	mg/kg	0.005	320	< 0.0050	< 0.0050	< 0.0050	< 0.0050	< 0.0050	< 0.0050	< 0.0050	< 0.0050	< 0.0050	< 0.0050	< 0.0050	< 0.0050
Acridine	mg/kg	0.01	ng	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010
Anthracene	mg/kg	0.004	2.5	< 0.0040	< 0.0040	< 0.0040	< 0.0040	< 0.0040	< 0.0040	< 0.0040	< 0.0040	< 0.0040	< 0.0040	< 0.0040	< 0.0040
Benzo(a)anthracene	mg/kg	0.005	0.1	< 0.0050	< 0.0050	< 0.0050	< 0.0050	< 0.0050	< 0.0050	< 0.0050	< 0.0050	< 0.0050	< 0.0050	< 0.0050	< 0.0050
Benzo(b&l)fluoranthene	mg/kg	0.005	0.1	0.013	0.0061	0.012	< 0.0050	< 0.0050	< 0.0050	< 0.0050	< 0.0050	0.0089	< 0.0050	0.007	0.011
Benzo(k)fluoranthene	mg/kg	0.005	0.1	< 0.0050	< 0.0050	< 0.0050	< 0.0050	< 0.0050	< 0.0050	< 0.0050	< 0.0050	< 0.0050	< 0.0050	< 0.0050	< 0.0050
Benzo(g,h,i)perylene	mg/kg	0.005	ng	0.0068	0.0078	0.0071	< 0.0050	0.0063	< 0.0050	< 0.0050	< 0.0050	0.0074	< 0.0050	0.0078	< 0.0050
Benzo(c)phenanthrene	mg/kg	0.005	ng	< 0.0050	< 0.0050	< 0.0050	< 0.0050	< 0.0050	< 0.0050	< 0.0050	< 0.0050	< 0.0050	< 0.0050	< 0.0050	< 0.0050
Benzo(a)pyrene	mg/kg	0.005	0.6	< 0.0050	< 0.0050	< 0.0050	< 0.0050	< 0.0050	< 0.0050	< 0.0050	< 0.0050	< 0.0050	< 0.0050	< 0.0050	< 0.0050
Benzo[e]pyrene	mg/kg	0.005	ng	0.0081	0.0083	0.0098	< 0.0050	< 0.0050	< 0.0050	< 0.0050	< 0.0050	0.0082	< 0.0050	0.0074	0.0075
Chrysene	mg/kg	0.005	6.2	< 0.0050	< 0.0050	< 0.0050	< 0.0050	< 0.0050	< 0.0050	< 0.0050	< 0.0050	< 0.0050	< 0.0050	< 0.0050	< 0.0050
Dibenz(a,h)anthracene	mg/kg	0.005	0.1	< 0.0050	< 0.0050	< 0.0050	< 0.0050	< 0.0050	< 0.0050	< 0.0050	< 0.0050	< 0.0050	< 0.0050	< 0.0050	< 0.0050
Fluoranthene	mg/kg	0.005	15.4	< 0.0050	< 0.0050	< 0.0050	< 0.0050	< 0.0050	< 0.0050	< 0.0050	< 0.0050	< 0.0050	< 0.0050	< 0.0050	< 0.0050
Fluorene	mg/kg	0.005	0.25	< 0.0050	< 0.0050	< 0.0050	< 0.0050	< 0.0050	< 0.0050	< 0.0050	< 0.0050	< 0.0050	< 0.0050	< 0.0050	< 0.0050
Indeno(1,2,3-cd)pyrene	mg/kg	0.005	0.1	0.0055	< 0.0050	< 0.0050	< 0.0050	< 0.0050	< 0.0050	< 0.0050	< 0.0050	< 0.0050	< 0.0050	< 0.0050	< 0.0050
2-Methylnaphthalene	mg/kg	0.005	ng	< 0.0050	0.0072	< 0.0050	< 0.0050	< 0.0050	< 0.0050	< 0.0050	0.0073	< 0.0050	0.0082	< 0.0050	< 0.0050
Naphthalene	mg/kg	0.005	0.013	< 0.0050	< 0.0050	< 0.0050	< 0.0050	< 0.0050	< 0.0050	< 0.0050	0.0062	< 0.0050	< 0.0050	< 0.0050	< 0.0050
Phenanthrene	mg/kg	0.005	0.046	< 0.0050	0.017	0.0094	0.0084	0.0084	0.0095	0.014	0.012	0.0087	0.016	0.0093	< 0.0050
Perylene	mg/kg	0.005	ng	0.0056	< 0.0050	< 0.0050	< 0.0050	< 0.0050	< 0.0050	< 0.0050	< 0.0050	< 0.0050	< 0.0050	< 0.0050	< 0.0050
Pyrene	mg/kg	0.005	0.1	< 0.0050	< 0.0050	< 0.0050	< 0.0050	< 0.0050	< 0.0050	< 0.0050	< 0.0050	< 0.0050	< 0.0050	< 0.0050	< 0.0050
Quinoline	mg/kg	0.01	0.1	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010
B(a)P TPE ^(b)	mg/kg	N/A	5.3	0.013	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10
IACR ^(b)	mg/kg	N/A	1.0	0.17	< 0.10	0.12	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	0.1	< 0.10	< 0.10	0.11

Notes:
(a) Canadian Council of Ministers of the Environment (CCME) Canadian Soil Quality Guidelines for the Protection of Environmental and Human Health for Polycyclic Aromatic Hydrocarbons, 2010, for agricultural land use in fine-grained soil.
(b) Refer to CCME Canadian Soil Quality Guidelines (CCME, 2010) for formulas used to calculate B(a)P TPE and IACR.
B(a)P TPE - Benzo(a)pyrene Total Potency Equivalents, which is the sum of estimated cancer potency relative to B(a)P for all potentially carcinogenic unsubstituted PAHs, for a 1 x 10⁻⁵ incremental lifetime cancer risk.
IACR - Index of Additive Cancer Risk assesses potential threats to potable groundwater quality from leaching of carcinogenic PAH mixtures from soil.

ppm - parts per million
m bgs - metres below ground surface
RDL - reported detection limit
N/A - not available
ng - no guideline

BOLD indicates samples in exceedance of applied guidelines.
Table should be read in conjunction with accompanying report.

**Table A.3
Summary of Soil Analytical Results - Metals
Bar U Ranch National Historic Site, Alberta
Public Works and Government Services Canada**

Reference or Exposure Location			CCME Guidelines ^(a)	Reference											
Sample Identification				GMW18-7	GMW19-1	GMW19-2	GMW19-9	GMW20-1	GMW20-2	GMW21-1	GMW21-2	GMW21-3	GBH22-1	GBH22-2	GBH22-3
Sample Depth (m bgs)				4.5 - 5.25	0.46-0.76	1.83-1.98	0.46-0.76	0.3-0.61	1.22-1.37	0.0-0.3	1.22-1.37	1.83-1.98	0-0.3	1.22-1.37	1.83-1.98
Headspace Combustible Vapour (ppm)				85	0	0	0	0	0	0	0	0	0	0	0
Sample Collection Date				20-Nov-15	24-Oct-16	25-Oct-16	25-Oct-16	25-Oct-16							
Parameter	Units	2016 RDL													
Total Antimony (Sb)	mg/kg	0.5	20	<0.50	< 0.50	< 0.50	0.54	< 0.50	0.51	< 0.50	< 0.50	< 0.50	0.57	< 0.50	< 0.50
Total Arsenic (As)	mg/kg	1	12	5.9	6.5	6.2	6.9	6.3	6.7	6.7	5.9	6	7	6.5	6.7
Total Barium (Ba)	mg/kg	1	750	190	420	430	470	330	400	290	310	290	320	390	380
Total Beryllium (Be)	mg/kg	0.4	4	0.51	0.8	0.72	0.97	0.74	1.1	0.88	0.8	0.88	1.1	0.77	1.1
Soluble (Hot water) Boron (B)	mg/kg	0.1	2	0.29	0.21	0.12	0.11	< 0.10	0.16	0.2	0.17	0.21	0.29	< 0.10	0.12
Total Cadmium (Cd)	mg/kg	0.05	1.4	0.6	0.38	0.43	0.4	0.38	0.51	0.43	0.46	0.46	0.55	0.37	0.44
Hex. Chromium (Cr 6+)	mg/kg	0.08	0.4	<0.080	< 0.080	< 0.080	< 0.080	< 0.080	< 0.080	< 0.080	< 0.080	< 0.080	< 0.080	< 0.080	< 0.080
Total Chromium (Cr)	mg/kg	1	64	18	19	19	24	16	25	22	20	20	26	17	25
Total Cobalt (Co)	mg/kg	0.5	40	6.6	7.1	7.4	8.4	6.6	8.7	7.6	7.2	7.5	8.8	7	8.6
Total Copper (Cu)	mg/kg	1	63	17	19	19	23	17	28	20	23	19	27	18	27
Total Lead (Pb)	mg/kg	0.5	70	9.9	11	11	13	9.9	12	11	11	11	13	11	12
Total Mercury (Hg)	mg/kg	0.05	6.6	0.13	< 0.050	< 0.050	< 0.050	< 0.050	< 0.050	< 0.050	< 0.050	< 0.050	< 0.050	< 0.050	< 0.050
Total Molybdenum (Mo)	mg/kg	0.4	5	0.92	0.67	0.85	0.71	0.68	0.93	0.71	0.82	0.84	0.74	0.71	0.94
Total Nickel (Ni)	mg/kg	1	45	23	24	24	28	21	30	25	24	24	31	23	28
Total Selenium (Se)	mg/kg	0.5	1	0.51	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50
Total Silver (Ag)	mg/kg	0.2	20	<0.20	< 0.20	< 0.20	< 0.20	< 0.20	< 0.20	< 0.20	< 0.20	< 0.20	< 0.20	< 0.20	< 0.20
Total Thallium (Tl)	mg/kg	0.1	1	0.19	0.17	0.17	0.2	0.16	0.22	0.16	0.19	0.2	0.23	0.16	0.22
Total Tin (Sn)	mg/kg	1	5	<1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0
Total Uranium (U)	mg/kg	0.2	23	0.88	0.71	0.93	0.79	0.67	0.99	0.48	1.1	1.2	0.65	0.74	1
Total Vanadium (V)	mg/kg	1	130	21	35	30	42	29	43	38	30	29	49	30	43
Total Zinc (Zn)	mg/kg	10	200	60	70	72	80	65	88	73	75	74	84	70	84

Notes:
 (a) Canadian Council of Ministers of the Environment (CCME) Canadian Soil Quality Guidelines for the Protection of Environmental and Human Health for agricultural land use, current to 2017.
 mg/kg - milligrams per kilogram
 ppm - parts per million
 m bgs - metres below ground surface
 RDL - reported detection limit

BOLD indicates samples in exceedance of applied guidelines.
 Table should be read in conjunction with accompanying report.

Table A.4
Summary of Soil Analytical Results - Detailed Salinity Parameters
Bar U Ranch National Historic Site, Alberta
Public Works and Government Services Canada

Reference or Exposure Location			CCME Guidelines ^(a)	Reference											
Sample Identification				GMW18-7	GMW19-1	GMW19-2	GMW19-9	GMW20-1	GMW20-2	GMW21-1	GMW21-2	GMW21-3	GBH22-1	GBH22-2	GBH22-3
Sample Depth (m bgs)				4.5 - 5.25	0.46-0.76	1.83-1.98	0.46-0.76	0.3-0.61	1.22-1.37	0.0-0.3	1.22-1.37	1.83-1.98	0-0.3	1.22-1.37	1.83-1.98
Headspace Combustible Vapour (ppm)				85	0	0	0	0	0	0	0	0	0	0	0
Sample Collection Date				20-Nov-15	24-Oct-16	25-Oct-16	25-Oct-16	25-Oct-16							
Parameter	Units	2016 RDL													
Calculated Parameters															
Calculated Calcium (Ca)	mg/kg	0.74	ng	170	33	11	21	23	17	130	180	190	55	65	250
Calculated Magnesium (Mg)	mg/kg	0.5	ng	240	12	11	12	5.2	12	18	960	870	8.6	58	360
Calculated Sodium (Na)	mg/kg	1.2	ng	190	18	11	18	8.9	15	7.8	570	560	14	31	250
Calculated Potassium (K)	mg/kg	0.64	ng	10	2.8	2.7	1.9	1.8	2.9	35	13	13	5	2.1	10
Calculated Chloride (Cl)	mg/kg	2.5	ng	3.5	11	4.7	9.9	5.5	7.6	28	20	10	11	130	29
Calculated Sulphate (SO4)	mg/kg	2.5	ng	1,700	31	27	29	21	32	41	4,900	4,900	35	230	2,300
Soluble Chloride (Cl)	mg/L	5	ng	7.2	19	8.3	16	11	9.8	36	30	16	15	280	43
Soluble Conductivity	dS/m	0.02	2	5.2	0.46	0.31	0.38	0.34	0.28	0.93	9	9.7	0.45	1.80	4.6
Soluble (CaCl2) pH	pH	N/A	6.0 - 8.0	7.74	7.6	7.75	7.74	7.71	7.72	7.42	7.92	7.93	7.44	7.86	7.81
Sodium Adsorption Ratio	N/A	0.1	5	3.2	0.9	0.75	0.98	0.62	0.8	0.2	4.7	4.8	0.56	0.98	2.9
Soluble Calcium (Ca)	mg/L	1.5	ng	340	56	19	33	46	22	160	270	310	76	140	360
Soluble Magnesium (Mg)	mg/L	1	ng	480	20	19	18	11	15	24	1,500	1,400	12	120	530
Soluble Nitrate (N)	mg/L	0.2	ng	0.24	-	-	-	-	-	-	-	-	-	-	-
Soluble Sodium (Na)	mg/L	2.5	ng	380	31	19	28	18	20	10	880	900	20	66	370
Soluble Potassium (K)	mg/L	1.3	ng	21	4.8	4.8	3	3.7	3.7	45	20	22	6.8	4.5	15
Soluble Sulphate (SO4)	exceedance	5	ng	3,500	53	48	47	43	42	54	7,500	7,900	48	480	3,300
Theoretical Gypsum Requirement	tonnes/ha	0.2	ng	<0.20	< 0.20	< 0.20	< 0.20	< 0.20	< 0.20	< 0.20	5.2	6.2	< 0.20	< 0.20	< 0.20

Notes:
(a) Canadian Council of Ministers of the Environment (CCME) Canadian Soil Quality Guidelines for the Protection of Environmental and Human Health for agricultural land use in fine grained soil, current to 2017.
mg/kg - milligrams per kilogram
mg/L - milligram per litre
dS/m - decisiemens per metre
tonnes/ha - tonnes per hectare
ppm - parts per million
RDL - reported detection limit
ng - no guideline
N/A - not available
- - not analyzed

BOLD indicates samples in exceedance of applied guidelines.

Table should be read in conjunction with accompanying report.

Table A.5
Summary of Soil Analytical Results - Waste Classification Analysis
Bar U Ranch National Historic Site, Alberta
Public Works and Government Services Canada

Sample Identification			Bar U Ranch 10-08-017-02 W5M	AEP Waste Guidelines^(a)
Sample Depth (m bgs)			N/A	
Sample Collection Date			24-Jan-17	
Parameters	Units	RDL		
Leachable BTEX				
Leachable (ZH) Benzene	mg/L	0.01	<0.02	0.5
Leachable (ZH) Toluene	mg/L	0.01	<0.02	0.5
Leachable (ZH) Ethylbenzene	mg/L	0.01	<0.02	0.5
Leachable (ZH) Xylenes (Total)	mg/L	0.02	<0.05	0.5
Leachable Metals				
Leachable Antimony (Sb)	mg/L	1	<10.0	500
Leachable Arsenic (As)	mg/L	0.5	<1.0	5
Leachable Barium (Ba)	mg/L	1	<10.0	100
Leachable Beryllium (Be)	mg/L	0.5	<1.0	5
Leachable Boron (B)	mg/L	1	<10.0	500
Leachable Cadmium (Cd)	mg/L	0.1	<0.5	1
Leachable Chromium (Cr)	mg/L	0.5	<1.0	5
Leachable Cobalt (Co)	mg/L	1	<10.0	100
Leachable Copper (Cu)	mg/L	1	<10.0	100
Leachable Iron (Fe)	mg/L	1	<10.0	1,000
Leachable Lead (Pb)	mg/L	0.5	<1.0	5
Leachable Mercury (Hg)	mg/L	0.02	<0.2	0.2
Leachable Nickel (Ni)	mg/L	0.5	<1.0	5
Leachable Selenium (Se)	mg/L	0.1	<0.5	1
Leachable Silver (Ag)	mg/L	0.5	<1.0	5
Leachable Thallium (Tl)	mg/L	0.5	<1.0	5
Leachable Uranium (U)	mg/L	0.2	<1.0	2
Leachable Vanadium (V)	mg/L	1	<10.0	100
Leachable Zinc (Zn)	mg/L	1	<10.0	500
Leachable Zirconium (Zr)	mg/L	1	<10.0	500
For Oil Analyses				
Flashpoint	°C	N/A	>61	>61
Physical Properties				
Free Liquid	N/A	N/A	PASS	-
Soluble Parameters				
Soluble (1:1) pH	pH	N/A	8.50	>2, <12.5

Notes:

(a) Alberta Environment and Parks (AEP), "Alberta User Guide for Waste Managers" Table 2 Class 9.3 Substances

RDL - reported detection limit

mg/L - milligrams per litre

°C - degrees Celsius

N/A - not applicable

BOLD

indicates samples in exceedance of applied guidelines.

Table should be read in conjunction with accompanying report.

Table A.6
Summary of Groundwater and Surface Water Field Monitoring Results
Bar U Ranch National Historic Site, Alberta
Public Works and Government Services Canada

ID	Reference or Exposure Location	Date	Depth to Groundwater (m btoc)	LNAPL Thickness (m)	Headspace Vapours (ppm)	Electrical Conductivity (µS/m)	pH	Temperature (°C)	Dissolved Oxygen (m/L)	GPS Coordinates (11U)		
										Northing	Easting	
GROUNDWATER												
MW1	Exposure	25-Oct-16	2.86	n/d	0	4,521	6.96	6.1	5.44	5,589,497	695,215	
		09-Jul-15	1.93	n/d	20	3,082	6.87	9.1	NA			
MW2			27-Oct-16	2.67	n/d	0	3,513	6.93	7.5	6.82	5,589,476	695,272
		10-Jul-15	2.08	n/d	15	1,820	6.84	9.1	NA			
MW3			27-Oct-16	2.85	n/d	0	7,462	6.94	9.5	7.37	5,589,467	695,272
		10-Jul-15	2.60	n/d	5	3,777	6.54	10.6	NA			
MW4			27-Oct-16	dry	n/d	0	Insufficient Water to Collect Parameters				5,589,559	695,380
		10-Jul-15	4.66	n/d	15	Insufficient Water to Collect Sample						
MW5			27-Oct-16	dry	n/d	15	Insufficient Water to Collect Parameters				5,589,553	695,460
		10-Jul-15	2.80	n/d	5							
MW6			25-Oct-16	1.90	n/d	0	3,477	6.98	8.6	2.45	5,589,538	695,446
		10-Jul-15	1.79	n/d	60	2,785	6.70	10.4	NA			
MW7			27-Oct-16	3.31	n/d	0	8,642	6.73	7.6	6.80	5,589,517	695,224
		09-Jul-15	2.37	n/d	10	6,563	6.71	6.9	NA			
MW8			25-Oct-16	2.69	n/d	0	9,316	7.08	6.4	8.37	5,589,497	695,216
		09-Jul-15	2.17	n/d	80	6,435	6.93	6.3	NA			
MW9			25-Oct-16	2.61	n/d	0	5,695	7.06	8.2	5.97	5,589,553	695,243
		09-Jul-15	2.05	n/d	40	2,012	7.04	10.6	NA			
MW10			27-Oct-16	Well Missing							NA	NA
		09-Jul-15										
MW11			27-Oct-16	Removed in 2009							NA	NA
		09-Jul-15										
MW12			25-Oct-16	2.04	n/d	0	2,296	7.06	7.8	3.65	5,589,533	695,469
		10-Jul-15	2.00	n/d	15	1,831	6.67	10.9	NA			
MW13			27-Oct-16	Well Missing							NA	NA
		09-Jul-15										
MW14			27-Oct-16	Well Missing							NA	NA
		09-Jul-15										
MW15		27-Oct-16	Well Missing							NA	NA	
	09-Jul-15											
MW16		27-Oct-16	Damaged/Flooded Out							5,589,493	695,479	
	09-Jul-15	Well Missing										
MW17		27-Oct-16	2.30	n/d	0	2,323	7.02	3.9	3.87	5,589,532	695,537	
	09-Jul-15	Well Missing							NA			
GMW18		27-Nov-15	4.90	n/d	0	9,393	7.06	5.7	7.87			
GMW19	Reference	14-Nov-16	4.62	n/d	0	2,791	7.93	2.9	4.79	5,589,508	695,155	
GMW20		14-Nov-16	5.79	n/d	0	Insufficient Water to Collect Parameters				5,589,596	695,160	
GMW21		14-Nov-16	5.41	n/d	0					5,589,610	695,237	
		14-Nov-16										
SURFACE WATER												
SW16-01	Reference	26-Oct-16	NA	NA	NA	405	8.19	5.9	17.63	5,589,340	695,579	
SW15-01		27-Nov-15	NA	NA	NA	450	8.30	-0.3	NA	5,589,115	695,620	
SW16-03		26-Oct-16	NA	NA	NA	405	8.19	6.1	11.82	5,589,295	695,616	
SW16-04		26-Oct-16	NA	NA	NA	405	8.16	6.2	11.05	5,589,215	695,626	
SW16-05		26-Oct-16	NA	NA	NA	405	8.17	6.2	14.01	5,589,146	695,633	
SW16-02	Exposure	26-Oct-16	NA	NA	NA	413	8.16	3.8	14.24	5,589,653	695,762	
SW15-02		27-Nov-15	NA	NA	NA	455	8.31	-0.4	NA	5,589,619	695,766	
SW16-06		26-Oct-16	NA	NA	NA	412	8.21	4.8	13.30	5,589,602	695,746	
SW16-07		26-Oct-16	NA	NA	NA	408	8.14	5.2	12.16	5,589,560	695,722	
SW16-08		27-Oct-16	NA	NA	NA	408	8.14	5.3	12.62	5,589,556	695,675	

Notes:
 LNAPL - Light Non-Aqueous Phase Liquid
 m bgs - metres below top of casing
 m - metres
 ppm - parts per million
 µS/m - microSiemens per metre
 °C - degrees Celsius
 n/d - not detected
 NA - not available
 Table should be read in conjunction with accompanying report.

Table A.7
Summary of Current and Historic Groundwater Analytical Results - Routine Chemistry Parameters
Bar U Ranch National Historic Site, Alberta
Public Works and Government Services Canada

Reference or Exposure Location	Monitoring Well	Sample Collection Date	Maxxam Sample ID	Parameters															
				Hardness (CaCO3)	Dissolved Nitrate (NO3)	Nitrate plus Nitrite (N)	Dissolved Nitrite (NO2)	Total Dissolved Solids	Conductivity	pH	Alkalinity (PP as CaCO3)	Alkalinity (Total as CaCO3)	Bicarbonate (HCO3)	Carbonate (CO3)	Hydroxide (OH)	Dissolved Sulphate (SO4)	Dissolved Chloride (Cl)	Dissolved Nitrite (N)	Dissolved Nitrate (N)
Units				mg/L	mg/L	mg/L	mg/L	mg/L	uS/cm	pH	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
2016 Reportable Detection Limit				0.5	0.044	0.02	0.033	10	1	none	0.5	0.5	0.5	0.5	1	1	0.01	0.01	
Health Canada ^(a)				ng	45	ng	3	500	ng	6.5 - 8.5	ng	ng	ng	ng	500	250	1	10	
FCSAP ^(b)				ng	13	100	ng	3000	ng	6.5 - 9	ng	ng	ng	ng	100	100	0.06	ng	
Exposure	MW1	31-Oct-06	N/A	N/A	N/A	N/A	N/A	6.880	N/A	7.80	N/A	N/A	N/A	N/A	N/A	4.670	8	<0.050	<0.05
		16-Dec-14	LJ9563	N/A	N/A	N/A	N/A	4.100	N/A	7.47	N/A	N/A	N/A	N/A	N/A	2.800	13	<0.010	0.017
		09-Jul-15	MQ2964	2,100	0.23	0.051	<0.033	4.100	4,500	7.74	<0.50	550	670	<0.50	<0.50	2.700	13	<0.010	0.051
		09-Jul-15	MQ2961 (Dup: DUP15-01)	2,100	0.21	0.047	<0.033	4.100	4,500	7.74	<0.50	550	670	<0.50	<0.50	2.700	13	<0.010	0.047
	MW2	28-Oct-16	PX2261	2,200	< 0.22	< 0.020	<0.16	4.200	4,500	7.63	< 0.50	570	700	< 0.50	< 0.50	2.700	15	<0.050	< 0.050
		16-Dec-14	LJ9567	N/A	N/A	N/A	N/A	1.600	N/A	7.84	N/A	N/A	N/A	N/A	N/A	790	11	<0.010	<0.010
		13-Jul-15	MQ5585	1,400	0.33	0.075	<0.033	2.500	3,200	7.86	<0.50	530	650	<0.50	<0.50	1.500	11	<0.010	0.075
	MW3	27-Oct-16	PX2253	1800	0.27	0.071	0.034	3.000	3,500	7.77	< 0.50	500	610	< 0.50	< 0.50	1.900	16	0.010	0.061
		15-Sep-06	N/A	N/A	N/A	N/A	N/A	2.430	N/A	7.90	N/A	N/A	N/A	N/A	N/A	1.510	21.8	<0.050	0.18
		03-Nov-06	N/A	N/A	N/A	N/A	N/A	3.310	N/A	7.60	N/A	N/A	N/A	N/A	N/A	2.140	34.3	<0.050	0.21
		18-Dec-14	LK1840	N/A	N/A	N/A	N/A	3.400	N/A	7.54	N/A	N/A	N/A	N/A	N/A	2.100	21	0.012	1.5
		13-Jul-15	MQ5586	3,900	0.88	0.2	<0.16	6.200	6,300	7.92	<0.50	620	760	<0.50	<0.50	4.200	32	<0.050	0.20
	MW4	28-Oct-16	PX2255	5,500	1.4	0.32	<0.16	8.400	7,800	7.62	< 0.50	700	860	< 0.50	< 0.50	5.700	37	<0.050	0.32
		31-Oct-06	N/A	N/A	N/A	N/A	N/A	6.670	N/A	7.80	N/A	N/A	N/A	N/A	N/A	4.220	1.7	<0.050	<0.05
		15-Sep-06	N/A	N/A	N/A	N/A	N/A	2.100	N/A	8.00	N/A	N/A	N/A	N/A	N/A	1.030	50.6	<0.050	<0.05
	MW6	18-Dec-14	LK1839	N/A	N/A	N/A	N/A	2.600	N/A	7.59	N/A	N/A	N/A	N/A	N/A	1.200	44	<0.010	0.012
		13-Jul-15	MQ5588	1,800	0.25	0.057	<0.16	3.000	3,900	7.84	<0.50	880	1,100	<0.50	<0.50	1.600	77	<0.050	0.057
28-Oct-16		PX2256	1,900	0.056	< 0.020	<0.033	2.800	3,500	7.71	< 0.50	810	980	< 0.50	< 0.50	1.400	67	<0.010	0.013	
QA/QC	MWDI (Duplicate of MW6)	28-Oct-16	PX2260	1,900	0.073	< 0.020	<0.033	2.900	3,400	7.73	< 0.50	810	990	< 0.50	< 0.50	1.500	67	<0.010	0.016
Exposure	MW7	31-Oct-06	N/A	N/A	N/A	N/A	4.950	N/A	7.90	N/A	N/A	N/A	N/A	N/A	3.330	7.2	<0.050	0.28	
		16-Dec-14	LJ9566	N/A	N/A	N/A	N/A	9.700	N/A	7.73	N/A	N/A	N/A	N/A	6.600	120	<0.010	7.6	
		09-Jul-15	MQ2965	7,200	37	8.3	<0.066	12.000	10,000	7.82	<0.50	530	640	<0.50	<0.50	8.300	130	<0.020	8.3
		27-Oct-16	PX2252	5,600	32	7.3	<0.16	9.200	8,700	7.61	< 0.50	550	670	< 0.50	< 0.50	6.300	78	<0.050	7.3
	MW8	31-Oct-06	N/A	N/A	N/A	N/A	N/A	12.000	N/A	7.80	N/A	N/A	N/A	N/A	N/A	8.390	3.1	<0.050	0.08
		16-Dec-14	LJ9564	N/A	N/A	N/A	N/A	9.100	N/A	7.58	N/A	N/A	N/A	N/A	N/A	6.600	9.6	<0.020	<0.020
		09-Jul-15	MQ2966	7,100	<0.44	<0.020	<0.33	11.000	9,700	7.88	<0.50	630	770	<0.50	<0.50	8.200	9.2	<0.010	<0.10
	MW9	28-Oct-16	PX2259	7000	< 0.22	< 0.020	<0.16	11.000	9,500	7.63	< 0.50	670	820	< 0.50	< 0.50	7.300	12	<0.050	< 0.050
		03-Nov-06	N/A	N/A	N/A	N/A	N/A	3.350	N/A	7.90	N/A	N/A	N/A	N/A	N/A	2.150	18.4	<0.050	0.26
		16-Dec-14	LJ9565	N/A	N/A	N/A	N/A	1.700	N/A	7.89	N/A	N/A	N/A	N/A	N/A	840	23	<0.010	0.035
		09-Jul-15	MQ2967	1,700	0.15	0.034	<0.033	2.500	3,100	8.06	<0.50	570	700	<0.50	<0.50	1.600	27	<0.050	0.034
	MW10	28-Oct-16	PX2258	4,600	0.41	0.093	<0.16	5.900	5,800	7.72	<0.50	660	800	<0.50	<0.50	3.900	27	<0.050	0.093
		31-Oct-06	N/A	N/A	0.89	N/A	N/A	9.940	N/A	7.90	N/A	N/A	N/A	N/A	N/A	7.120	3.6	<0.050	0.89
	MW12	31-Oct-06	N/A	N/A	N/A	N/A	N/A	1.260	N/A	8.00	N/A	N/A	N/A	N/A	N/A	656	16.4	<0.050	<0.05
		18-Dec-14	LK1838	N/A	N/A	N/A	N/A	1.700	N/A	7.70	N/A	N/A	N/A	N/A	N/A	870	13	<0.010	0.035
		09-Jul-15	MQ2968	1,400	0.12	0.027	<0.066	2.100	2,500	7.93	<0.50	480	590	<0.50	<0.50	1.200	16	<0.020	0.027
		27-Oct-16	PX2254	1,300	< 0.22	< 0.020	<0.033	1.900	2,300	7.74	< 0.50	420	510	< 0.50	< 0.50	1.100	16	<0.010	< 0.050
MW13	31-Oct-06	N/A	N/A	N/A	N/A	N/A	1.300	N/A	8.00	N/A	N/A	N/A	N/A	N/A	647	14.9	<0.050	1	
MW14	28-Nov-08	N/A	N/A	N/A	N/A	N/A	606	N/A	8.00	N/A	N/A	N/A	N/A	N/A	184	NA	<0.050	6.36	
MW16	28-Nov-08	N/A	N/A	N/A	N/A	N/A	294	N/A	8.09	N/A	N/A	N/A	N/A	N/A	47	11	<0.050	0.21	
MW17	28-Oct-16	PX2257	280	0.29	0.065	<0.033	320	510	7.99	< 0.50	240	290	< 0.50	< 0.50	42	2.5	<0.010	0.065	
Reference	GMW18	27-Nov-15	NS8667	6,200	0.43	0.096	<0.16	11.000	10,000	7.81	<0.50	820	1,000	<0.50	<0.50	8.100	11	<0.050	0.096
		27-Oct-16	PX2251	6,400	0.37	0.083	<0.16	11.000	9,800	7.57	< 0.50	900	1100	< 0.50	< 0.50	7.400	6.8	<0.050	0.083
	GMW19	15-Nov-16	QB0518	1,700	0.26	0.072	0.046	2.400	2,900	7.72	< 0.50	580	710	< 0.50	< 0.50	1.400	3	0.014	0.058
	GMW20	16-Nov-16	QB0519	1,200	7.1	1.7	0.39	1.800	2,200	7.91	<0.50	420	510	<0.50	<0.50	1.000	17	0.12	1.6
GMW21	16-Nov-16	QB0520	12,000	2.2	0.58	0.27	21.000	17,000	7.7	< 0.50	830	1,000	< 0.50	< 0.50	15.000	10	0.083	0.5	
QA/QC	Field Blank	28-Oct-16	PX2262	< 0.50	< 0.044	< 0.020	<0.033	< 10	< 1.0	4.66	< 0.50	< 0.50	< 0.50	< 0.50	< 1.0	< 1.0	<0.010	< 0.010	
	Trip Blank	28-Oct-16	PX2263	< 0.50	< 0.044	< 0.020	<0.033	< 10	< 1.0	4.54	< 0.50	< 0.50	< 0.50	< 0.50	< 1.0	< 1.0	<0.010	< 0.010	

Notes:
(a) Health Canada Guidelines for Canadian Drinking Water Quality, October 2014.
(b) Federal Contaminated Sites Action Plan (FCSAP) Federal Interim Groundwater Quality Guidelines (FIGQGs) for Federal Contaminated Sites. Table 1: Tier 2 Guidelines for fine-grained soil and agricultural land use, with the Marine Life pathway excluded, June 2016, version 4.
RDL - reported detection limit

mg/L - milligrams per litre

uS/cm - microSiemens per centimeter

N/A - not available

< - less than

NC - not calculated

ng - no guideline

QA/QC - Quality Assurance Quality Control

BOLD indicates samples in exceedance of applied guideline.

BOLD indicates the reportable detection limit exceeded the applied guidelines.

Table should be read in conjunction with accompanying report.

Table A.8
Summary of Current and Historic Groundwater Analytical Results - Dissolved Metals
Bar U Ranch National Historic Site, Alberta
Public Works and Government Services Canada

Reference or Exposure Location	Monitoring Well	Sample Collection Date	Maxxam Sample ID	Dissolved Aluminum (Al)	Dissolved Antimony (Sb)	Dissolved Arsenic (As)	Dissolved Barium (Ba)	Dissolved Beryllium (Be)	Dissolved Boron (B)	Dissolved Cadmium (Cd)	Dissolved Calcium (Ca)	Dissolved Chromium (Cr)	Dissolved Cobalt (Co)	Dissolved Copper (Cu)
				mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
Units				mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
2016 Reportable Detection Limit				0.003	0.0006	0.0002	0.01	0.001	0.02	0.00002	0.3	0.001	0.0003	0.0002
Health Canada ^(a)				0.1	0.006	0.010	1.0	ng	5	0.005	ng	0.05	ng	1.0
FCSAP ^(b)				0.1	2	0.005	2.9	0.0053	0.5	0.00037	ng	0.0089	0.05	0.004
Exposure	MW1	20-Oct-04	N/A	<0.005	0.0011	<0.002	0.081	N/A	0.083	<0.0001	N/A	<0.005	N/A	0.0008
		28-Nov-08	N/A	0.05	N/A	N/A	0.026	N/A	0.12	<0.001	N/A	<0.005	N/A	0.007
		16-Dec-14	LJ9563	0.005	<0.00060	0.00076	0.03	N/A	0.093	<0.000020	350	<0.0010	N/A	0.00049
		09-Jul-15	MQ2964	0.0057	<0.00060	0.00063	0.015	<0.0010	0.097	0.000038	390	<0.0010	0.0032	0.0012
		09-Jul-15	MQ2961 (Dup: DUP15-01)	0.0065	<0.00060	0.0007	0.015	<0.0010	0.1	0.000054	390	<0.0010	0.0033	0.0012
	MW2	28-Oct-16	PX2261	< 0.0030	< 0.00060	0.00055	0.015	< 0.0010	0.11	0.00005	400	< 0.0010	0.0023	0.00068
		04-Nov-04	N/A	<0.005	<0.0005	<0.002	0.07	N/A	0.117	<0.0001	N/A	<0.005	N/A	0.0017
		16-Dec-14	LJ9567	0.0037	<0.00060	0.00076	0.025	N/A	0.066	<0.000020	140	<0.0010	N/A	0.0024
		13-Jul-15	MQ5586	<0.0030	<0.00060	0.00059	0.026	<0.0010	0.11	0.0002	260	<0.0010	0.0025	0.00084
	MW3	27-Oct-16	PX2253	0.0059	< 0.00060	0.00055	0.025	< 0.0010	0.16	0.000047	290	< 0.0010	0.0015	0.00013
		15-Sep-06	N/A	<0.01	N/A	N/A	0.086	N/A	0.15	<0.001	275	<0.005	N/A	0.005
		31-Oct-06	N/A	<0.01	0.0007	0.0012	0.085	N/A	0.19	0.0002	364	<0.005	N/A	0.004
		28-Nov-08	N/A	<0.01	N/A	N/A	0.043	N/A	0.06	<0.001	N/A	<0.005	N/A	0.002
		18-Dec-14	LK1840	0.0044	<0.00060	0.00077	0.036	N/A	0.12	0.000032	300	<0.0010	N/A	0.0021
		13-Jul-15	MQ5585	0.0039	<0.00060	0.00084	0.053	<0.0010	0.11	0.00025	560	<0.0010	0.00058	0.0037
	MW4	28-Oct-16	PX2255	0.0036	< 0.00060	0.0011	0.042	< 0.0010	0.14	0.00028	680	< 0.0010	0.00031	0.0075
		20-Oct-04	N/A	<0.005	0.0014	<0.002	0.055	N/A	0.168	<0.0001	N/A	<0.005	N/A	<0.005
	MW6	28-Nov-08	N/A	0.1	N/A	N/A	0.035	N/A	0.17	<0.001	N/A	<0.005	N/A	0.008
		20-Oct-04	N/A	<0.005	0.0006	<0.002	0.256	N/A	0.049	<0.0001	N/A	<0.005	N/A	0.0017
		28-Nov-08	N/A	0.01	N/A	N/A	0.053	N/A	0.08	<0.001	N/A	<0.005	N/A	0.002
18-Dec-14		LK1839	0.0055	<0.00060	0.0057	0.042	N/A	0.088	<0.000020	270	<0.0010	N/A	<0.00020	
13-Jul-15		MQ5588	0.005	<0.00060	0.001	0.034	<0.0010	0.089	<0.000020	280	<0.0010	<0.00030	<0.00020	
28-Oct-16	PX2256	0.0062	< 0.00060	0.00078	0.044	< 0.0010	0.11	< 0.000020	280	< 0.0010	< 0.00030	< 0.00033		
QA/QC	MWDI (Duplicate of MW6)	28-Oct-16	PX2260	0.0074	< 0.00060	0.00096	0.043	< 0.0010	0.1	< 0.000020	280	< 0.0010	< 0.00030	< 0.00020
Exposure	MW7	31-Oct-06	N/A	<0.01	0.0004	0.0010	0.076	N/A	0.12	<0.0001	488	<0.005	N/A	0.005
		16-Dec-14	LJ9566	<0.0030	<0.00060	0.0014	0.023	N/A	0.076	0.000053	440	<0.0010	N/A	0.0077
		09-Jul-15	MQ2965	0.0042	<0.00060	0.0011	0.018	<0.0010	0.064	0.000074	460	<0.0010	0.00088	0.0082
		27-Oct-16	PX2252	< 0.0030	< 0.00060	0.001	0.018	< 0.0010	0.093	0.00006	440	< 0.0010	0.00051	0.0065
	MW8	31-Oct-06	N/A	<0.01	0.0004	0.0020	0.068	N/A	0.07	0.0001	620	<0.005	N/A	0.012
		16-Dec-14	LJ9564	0.0041	<0.00060	0.0013	0.05	N/A	0.043	0.000027	290	<0.0010	N/A	0.0013
		09-Jul-15	MQ2966	0.0048	<0.00060	0.0013	0.014	<0.0010	0.041	0.00022	320	<0.0010	0.0067	0.0043
	MW9	28-Oct-16	PX2259	< 0.0030	< 0.00060	0.0015	0.015	< 0.0010	0.053	0.00086	350	< 0.0010	0.0054	0.0037
		31-Oct-06	N/A	<0.01	0.0013	0.0013	0.132	N/A	0.13	<0.0001	165	<0.005	N/A	0.006
		09-Jul-15	MQ2967	0.0084	<0.00060	0.0011	0.11	<0.0010	0.11	0.000037	150	<0.0010	0.0054	0.0027
		28-Oct-16	PX2258	< 0.0030	< 0.00060	0.0015	0.045	< 0.0010	0.21	< 0.000020	240	< 0.0010	0.0045	0.0021
	MW10	31-Oct-06	N/A	<0.01	<0.0004	0.0014	0.072	N/A	0.11	<0.0001	556	0.007	N/A	0.012
		31-Oct-06	N/A	<0.001	0.0004	0.0007	0.181	N/A	0.08	<0.0001	166	<0.005	N/A	0.003
		18-Dec-14	LK1838	0.0039	<0.00060	0.00041	0.085	N/A	0.055	0.00003	260	<0.0010	N/A	0.0021
		27-Oct-16	PX2254	< 0.0030	< 0.00060	0.00037	0.061	< 0.0010	0.066	0.000041	250	< 0.0010	< 0.00030	0.0025
		31-Oct-06	N/A	<0.01	0.0007	0.0007	0.047	N/A	0.10	<0.0001	161	<0.005	N/A	0.003
	MW12	28-Nov-08	N/A	<0.01	N/A	N/A	0.093	N/A	0.05	<0.001	N/A	<0.005	N/A	0.002
28-Nov-08		N/A	<0.01	N/A	N/A	0.11	N/A	<0.05	<0.001	N/A	<0.005	N/A	<0.001	
Reference	GMW18	28-Oct-16	PX2257	<0.0030	<0.00060	0.00032	0.057	<0.0010	0.076	0.031	78	<0.0010	<0.00030	0.0011
		27-Nov-15	NS8667	0.0056	<0.00060	0.0014	0.023	<0.0010	0.14	0.00026	410	<0.0010	0.0062	0.0034
	GMW19	27-Oct-16	PX2251	0.0062	< 0.00060	0.0013	0.016	< 0.0010	0.15	0.00021	380	< 0.0010	0.0048	0.0025
		15-Nov-16	QB0518	0.0034	< 0.00060	0.00082	0.038	< 0.0010	0.097	0.00006	250	< 0.0010	< 0.00030	0.0018
		16-Nov-16	QB0519	0.037	< 0.00060	0.00055	0.043	< 0.0010	0.075	0.000069	230	< 0.0010	< 0.00030	0.0029
GMW20	16-Nov-16	QB0520	0.026	< 0.00060	0.0018	< 0.20	< 0.0010	< 0.40	0.00025	400	< 0.0010	0.011	0.0077	
QA/QC	Field Blank	28-Oct-16	PX2262	< 0.0030	< 0.00060	< 0.00020	< 0.010	< 0.0010	< 0.020	< 0.000020	< 0.30	< 0.0010	< 0.00030	< 0.00020
	Trip Blank	28-Oct-16	PX2263	< 0.0030	< 0.00060	< 0.00020	< 0.010	< 0.0010	< 0.020	< 0.000020	< 0.30	< 0.0010	< 0.00030	< 0.00020

Notes:
(a) Health Canada Guidelines for Canadian Drinking Water Quality, October 2014.
(b) Federal Contaminated Sites Action Plan (FCSAP) Federal Interim Groundwater Quality Guidelines (FIGQGs) for Federal Contaminated Sites. Table 1: Tier 2 Guidelines for fine-grained soil and agricultural land use, with the Marine Life pathway excluded, June 2016, version 4.
FCSAP guidelines for aluminum (considering pH), and cadmium, copper, lead and nickel (considering hardness) were determined based on FCSAP guidance, including reference to CCME calculations. For aluminum, pH >6.5 at the Site, as such guideline of 100 ug/L was used. For hardness dependent parameters, CCME calculations were conducted using the CCME online calculator using the minimum hardness of all groundwater quality samples collected at the Site (i.e., 280 mg/L). Source: Canadian Council of Ministers of the Environment (CCME) Canadian Water Quality Guidelines for the Protection of Freshwater Aquatic Life (FAL), current to 2017.
RDL - reported detection limit
mg/L - milligrams per litre
N/A - not available
< - less than
ng - no guideline
QA/QC - Quality Assurance Quality Control
BOLD indicates samples in exceedance of applied guideline.
BOLD indicates the reportable detection limit exceeded the applied guideline

Table should be read in conjunction with accompanying report.
Golden Associates
[https://goldenassociates.sharepoint.com/sites/231819/Deliverables/RA Report/Final report/Appendix A - Analytical Results/1603024 - Bar U Analytical Results.xlsx](https://goldenassociates.sharepoint.com/sites/231819/Deliverables/RA%20Report/Final%20report/Appendix%20A%20Analytical%20Results/1603024%20Bar%20U%20Analytical%20Results.xlsx)
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Table A.8
Summary of Current and Historic Groundwater Analytical Results - Dissolved Metals
Bar U Ranch National Historic Site, Alberta
Public Works and Government Services Canada

Reference or Exposure Location	Monitoring Well	Sample Collection Date	Maxxam Sample ID	Parameters											
				Dissolved Iron (Fe)	Dissolved Lead (Pb)	Dissolved Lithium (Li)	Dissolved Magnesium (Mg)	Dissolved Manganese (Mn)	Dissolved Molybdenum (Mo)	Dissolved Nickel (Ni)	Dissolved Phosphorus (P)	Dissolved Potassium (K)	Dissolved Selenium (Se)	Dissolved Silicon (Si)	
Units				mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
2016 Reportable Detection Limit				0.06	0.0002	0.02	0.2	0.004	0.0002	0.0005	0.1	0.3	0.0002	0.1	
Health Canada ^(a)				0.3	0.010	ng	ng	0.05	ng	ng	ng	ng	0.05	ng	
FCSAP ^(b)				0.3	0.007	ng	ng	0.2	0.073	0.150	ng	ng	0.001	ng	
Exposure	MW1	20-Oct-04	N/A	<0.03	<0.0005	N/A	N/A	<0.005	N/A	<0.01	N/A	N/A	0.005	N/A	
		28-Nov-08	N/A	0.117	<0.005	N/A	N/A	2.74	N/A	0.028	N/A	N/A	N/A	N/A	
		16-Dec-14	LJ9563	0.21	<0.00020	N/A	290	1.8	N/A	0.011	N/A	9.8	0.0066	N/A	
		09-Jul-15	MQ2964	0.56	0.00049	0.063	270	1.9	0.0011	0.01	<0.10	6.5	<0.00020	4.7	
		09-Jul-15	MQ2961 (Dup: DUP15-01)	0.57	0.00044	0.067	260	1.9	0.0012	0.011	<0.10	6.5	<0.00020	4.7	
	MW2	28-Oct-16	PX2261	0.068	< 0.00020	0.071	300	1.7	0.00084	0.0084	< 0.10	8	0.00029	5.1	
		04-Nov-04	N/A	<0.03	<0.0005	N/A	N/A	<0.005	N/A	<0.001	N/A	N/A	0.021	N/A	
		16-Dec-14	LJ9567	1.5	<0.00020	N/A	130	0.52	N/A	0.0054	N/A	4.5	0.00068	N/A	
	MW3	13-Jul-15	MQ5586	0.33	0.0003	0.053	180	0.64	0.0011	0.0077	<0.10	6.1	0.0019	4.2	
		27-Oct-16	PX2253	0.068	< 0.00020	0.078	250	0.62	0.00098	0.0064	< 0.10	9	0.0019	4.9	
		15-Sep-06	N/A	0.016	<0.005	N/A	205	0.671	N/A	0.015	N/A	18.9	0.0027	N/A	
		31-Oct-06	N/A	0.089	<0.0001	N/A	285	1.46	N/A	0.018	N/A	23.1	0.0017	N/A	
		28-Nov-08	N/A	0.006	<0.005	N/A	N/A	0.152	N/A	0.005	N/A	N/A	N/A	N/A	
	MW4	18-Dec-14	LK1840	0.1	<0.00020	N/A	330	0.13	N/A	0.0053	N/A	17	0.00082	N/A	
		13-Jul-15	MQ5585	0.54	0.0003	0.04	620	0.15	0.0017	0.008	<0.10	19	0.00041	5.2	
		28-Oct-16	PX2255	< 0.060	< 0.00020	0.057	920	0.083	0.002	0.0068	< 0.10	28	0.00048	5.3	
		20-Oct-04	N/A	0.03	<0.0005	N/A	N/A	0.008	N/A	0.015	N/A	N/A	0.008	N/A	
	MW6	28-Nov-08	N/A	2.88	<0.005	N/A	N/A	2.63	N/A	0.057	N/A	N/A	N/A	N/A	
		20-Oct-04	N/A	0.07	<0.0005	N/A	N/A	0.934	N/A	0.013	N/A	N/A	N/A	N/A	
		28-Nov-08	N/A	1.17	<0.005	N/A	N/A	0.282	N/A	0.005	N/A	N/A	N/A	N/A	
		18-Dec-14	LK1839	3	<0.00020	N/A	240	0.19	N/A	0.0038	N/A	18	0.0066	N/A	
		13-Jul-15	MQ5588	1.8	0.00066	0.089	260	0.26	0.0012	0.0014	0.1	17	0.02	4.3	
	28-Oct-16	PX2256	1.3	< 0.00020	0.099	290	0.18	0.0029	0.00089	< 0.10	15	0.0024	5.1		
	QA/QC	MWDI (Duplicate of MW6)	28-Oct-16	PX2260	1.7	< 0.00020	0.081	280	0.2	0.005	0.0009	0.15	14	0.002	5.3
Exposure	MW7	31-Oct-06	N/A	<0.005	<0.00001	N/A	383	<0.001	N/A	0.013	N/A	12	0.0040	N/A	
		16-Dec-14	LJ9566	<0.060	<0.00020	N/A	1,300	<0.0040	N/A	0.0048	N/A	12	0.019	N/A	
		09-Jul-15	MQ2965	0.72	0.0016	0.12	1,500	<0.0040	0.0016	0.0045	0.11	11	0.018	3.8	
		27-Oct-16	PX2252	< 0.060	< 0.00020	0.13	1100	< 0.0040	0.0012	0.0033	< 0.10	14	0.014	4.4	
	MW8	31-Oct-06	N/A	<0.005	<0.0001	N/A	1,480	0.183	N/A	0.021	N/A	13.8	0.0019	N/A	
		16-Dec-14	LJ9564	0.085	<0.00020	N/A	1,100	2.4	N/A	0.026	N/A	12	0.00086	N/A	
		09-Jul-15	MQ2966	0.74	0.0016	0.068	1,500	2.9	0.0021	0.026	0.11	6.5	0.00064	4.2	
	MW9	28-Oct-16	PX2259	0.17	< 0.00020	0.076	1500	3.2	0.0021	0.024	< 0.10	7.9	0.00053	4.8	
		31-Oct-06	N/A	<0.005	<0.0001	N/A	347	0.022	N/A	0.009	N/A	5	0.0088	N/A	
		09-Jul-15	MQ2967	0.43	0.00081	0.049	330	2.2	0.0024	0.017	<0.10	4.1	0.00042	5.4	
		28-Oct-16	PX2258	0.5	< 0.00020	0.095	970	1.2	0.003	0.012	< 0.10	3.5	0.00031	4.8	
	MW10	31-Oct-06	N/A	<0.005	<0.001	N/A	1,040	<0.001	N/A	0.017	N/A	17.9	0.0502	N/A	
		31-Oct-06	N/A	0.008	<0.0001	N/A	95.1	0.123	N/A	0.007	N/A	10.2	0.0021	N/A	
		18-Dec-14	LK1838	0.077	<0.00020	N/A	150	0.38	N/A	0.0027	N/A	10	0.00027	N/A	
		27-Oct-16	PX2254	< 0.060	< 0.00020	0.024	170	0.075	0.0016	0.0022	< 0.10	12	0.00048	3.5	
		31-Oct-06	N/A	<0.005	<0.0001	N/A	114	0.093	N/A	0.005	N/A	6.6	0.0107	N/A	
	MW12	28-Nov-08	N/A	0.006	<0.005	N/A	N/A	0.113	N/A	0.003	N/A	N/A	N/A	N/A	
28-Nov-08		N/A	<0.005	<0.005	N/A	N/A	0.008	N/A	0.003	N/A	N/A	N/A	N/A		
MW13	28-Oct-16	PX2257	<0.060	<0.00020	<0.020	22	0.070	0.0013	0.00096	<0.10	2.3	0.00057	4.0		
	27-Nov-15	NS8667	<0.060	<0.00020	0.15	1,300	0.98	0.003	0.022	<0.10	17	0.0024	5.9		
Reference	GMW18	27-Oct-16	PX2251	< 0.060	< 0.00020	0.17	1300	1.9	0.0014	0.014	< 0.10	18	0.00067	5.6	
		15-Nov-16	QB0518	0.26	< 0.00020	0.069	250	0.05	0.0012	0.0022	< 0.10	8.8	0.00043	4.6	
	GMW20	16-Nov-16	QB0519	0.22	< 0.00020	0.056	160	0.02	0.0014	0.0026	< 0.10	9.3	0.0043	5.1	
	GMW21	16-Nov-16	QB0520	3.6	0.00026	< 0.40	2700	2.5	0.0046	0.019	< 2.0	25	0.0019	4.9	
QA/QC	Field Blank	28-Oct-16	PX2262	< 0.060	< 0.00020	< 0.020	< 0.20	< 0.0040	< 0.00020	< 0.00050	< 0.10	< 0.30	< 0.00020	< 0.10	
	Trip Blank	28-Oct-16	PX2263	< 0.060	< 0.00020	< 0.020	< 0.20	< 0.0040	< 0.00020	< 0.00050	< 0.10	< 0.30	< 0.00020	< 0.10	

Notes:
(a) Health Canada Guidelines for Canadian Drinking Water Quality, October 2014.
(b) Federal Contaminated Sites Action Plan (FCSAP) Federal Interim Groundwater Quality Guidelines (FIGQGs) for Federal Contaminated Sites. Table 1: Tier 2 Guidelines for fine-grained soil and agricultural land use, with the Marine Life pathway excluded, June 2016, version 4.
FCSAP guidelines for aluminum (considering pH), and cadmium, copper, lead and nickel (considering hardness) were determined based on FCSAP guidance, including reference to CCME calculations. For aluminum, pH >6.5 at the Site, as such guideline of 100 ug/L was used. For hardness dependent parameters, CCME calculations were conducted using the CCME online calculator using the minimum hardness of all groundwater quality samples collected at the Site (i.e., 280 mg/L). Source: Canadian Council of Ministers of the Environment (CCME) Canadian Water Quality Guidelines for the Protection of Freshwater Aquatic Life (FAL), current to 2017.
RDL - reported detection limit
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ng - no guideline
QA/QC - Quality Assurance Quality Control
BOLD indicates samples in exceedance of applied guideline.
BOLD indicates the reportable detection limit exceeded the applied guideline
Table should be read in conjunction with accompanying report.

Table A.8
Summary of Current and Historic Groundwater Analytical Results - Dissolved Metals
Bar U Ranch National Historic Site, Alberta
Public Works and Government Services Canada

Reference or Exposure Location	Monitoring Well	Sample Collection Date	Maxxam Sample ID	Dissolved Silver (Ag)	Dissolved Sodium (Na)	Dissolved Strontium (Sr)	Dissolved Sulphur (S)	Dissolved Thallium (Tl)	Dissolved Tin (Sn)	Dissolved Titanium (Ti)	Dissolved Uranium (U)	Dissolved Vanadium (V)	Dissolved Zinc (Zn)	
				mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
Units				mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	
2016 Reportable Detection Limit				0.0001	0.5	0.02	0.2	0.0002	0.001	0.001	0.0001	0.001	0.003	
Health Canada ^(a)				ng	200	ng	ng	ng	ng	ng	0.02	ng	5	
FCSAP ^(b)				0.00025	ng	ng	ng	0.0008	ng	0.1	0.01	0.1	0.03	
Exposure	MW1	20-Oct-04	N/A	<0.00010	N/A	N/A	N/A	N/A	N/A	N/A	0.0201	N/A	<0.05	
		28-Nov-08	N/A	<0.005	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0.004	
		16-Dec-14	LJ9563	<0.00010	370	N/A	N/A	N/A	N/A	N/A	N/A	0.02	N/A	<0.0030
		09-Jul-15	MQ2964	<0.00010	380	4.6	910	<0.00020	<0.0010	<0.0010	0.019	<0.0010	0.0092	
		09-Jul-15	MQ2961 (Dup: DUP15-01)	<0.00010	380	4.7	840	<0.00020	<0.0010	<0.0010	0.019	<0.0010	0.0088	
	MW2	28-Oct-16	PX2261	<0.00010	440	4.9	850	<0.00020	<0.0010	<0.0010	0.015	<0.0010	<0.0030	
		04-Nov-04	N/A	<0.00010	N/A	N/A	N/A	N/A	N/A	N/A	0.0243	N/A	<0.005	
		16-Dec-14	LJ9567	<0.00010	180	N/A	N/A	N/A	N/A	N/A	0.029	N/A	<0.0030	
		13-Jul-15	MQ5586	<0.00010	220	3.1	430	<0.00020	<0.0010	<0.0010	0.023	<0.0010	0.02	
	MW3	27-Oct-16	PX2253	<0.00010	310	4	590	<0.00020	<0.0010	<0.0010	0.017	<0.0010	<0.0030	
		15-Sep-06	N/A	<0.005	148	N/A	N/A	N/A	N/A	N/A	<0.05	N/A	0.026	
		31-Oct-06	N/A	0.0002	187	N/A	N/A	N/A	N/A	N/A	0.0130	N/A	0.052	
		28-Nov-08	N/A	<0.005	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0.003	
		18-Dec-14	LK1840	<0.00010	250	N/A	N/A	N/A	N/A	N/A	0.016	N/A	0.0052	
	MW4	13-Jul-15	MQ5585	<0.00010	340	3.1	1,300	<0.00020	<0.0010	<0.0010	0.028	<0.0010	0.042	
		28-Oct-16	PX2255	<0.00010	600	4.5	1,900	<0.00020	<0.0010	<0.0010	0.032	<0.0010	0.0093	
		20-Oct-04	N/A	<0.00010	N/A	N/A	N/A	N/A	N/A	N/A	0.0253	N/A	<0.05	
		28-Nov-08	N/A	<0.005	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0.007	
	MW6	20-Oct-04	N/A	<0.00010	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0.0076	N/A	<0.005
		28-Nov-08	N/A	<0.005	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0.002
		18-Dec-14	LK1839	<0.00010	210	N/A	N/A	N/A	N/A	N/A	0.0092	N/A	<0.0030	
		13-Jul-15	MQ5588	<0.00010	230	3.4	770	<0.00020	<0.0010	<0.0010	0.0046	0.0017	<0.0030	
	QA/QC	MWDI (Duplicate of MW6)	28-Oct-16	PX2260	<0.00010	250	3.1	490	<0.00020	<0.0010	<0.0010	0.0036	0.001	<0.0030
			31-Oct-06	N/A	<0.00010	434	N/A	N/A	N/A	N/A	N/A	0.0385	N/A	0.024
Exposure	MW7	16-Dec-14	LJ9566	<0.00010	850	N/A	N/A	N/A	N/A	N/A	0.1	N/A	<0.0030	
		09-Jul-15	MQ2965	0.00046	930	11	2,800	<0.00020	<0.0010	<0.0010	0.099	<0.0010	<0.0030	
		27-Oct-16	PX2252	<0.00010	850	9	2,200	<0.00020	<0.0010	<0.0010	0.062	<0.0010	<0.0030	
		31-Oct-06	N/A	<0.00010	1,130	N/A	N/A	N/A	N/A	N/A	0.0474	N/A	0.023	
	MW8	16-Dec-14	LJ9564	<0.00010	760	N/A	N/A	N/A	N/A	N/A	0.047	N/A	0.0063	
		09-Jul-15	MQ2966	0.0005	1,000	6.9	2,800	0.00022	<0.0010	<0.0010	0.05	<0.0010	0.023	
		28-Oct-16	PX2259	<0.00010	1,100	6.6	2,700	0.00034	<0.0010	<0.0010	0.041	<0.0010	0.017	
	MW9	31-Oct-06	N/A	<0.00010	298	N/A	N/A	N/A	N/A	N/A	0.0361	N/A	0.023	
		09-Jul-15	MQ2967	0.00027	130	2.2	440	<0.00020	<0.0010	<0.0010	0.020	0.0023	0.027	
		28-Oct-16	PX2258	<0.00010	340	5	1,500	<0.00020	<0.0010	<0.0010	0.056	<0.0010	<0.0030	
	MW10	31-Oct-06	N/A	<0.00010	933	N/A	N/A	N/A	N/A	N/A	0.0503	N/A	0.016	
		31-Oct-06	N/A	<0.00010	61	N/A	N/A	N/A	N/A	N/A	0.0095	N/A	0.024	
		18-Dec-14	LK1838	<0.00010	82	N/A	N/A	N/A	N/A	N/A	0.019	N/A	<0.0030	
		27-Oct-16	PX2254	<0.00010	120	1.5	350	<0.00020	<0.0010	<0.0010	0.012	<0.0010	<0.0030	
		31-Oct-06	N/A	<0.00010	78	N/A	N/A	N/A	N/A	N/A	0.0179	N/A	0.015	
		28-Nov-08	N/A	<0.005	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	<0.002	
28-Nov-08		N/A	<0.005	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	<0.002		
Reference	GMW18	28-Oct-16	PX2257	<0.00010	30	0.53	21	<0.00020	<0.0010	<0.0010	0.00072	<0.0010	<0.0030	
		27-Nov-15	NS8667	<0.00010	1,000	9.3	2,400	<0.00020	<0.0010	<0.0010	0.08	<0.0010	0.0057	
	27-Oct-16	PX2251	<0.00010	1,100	11	2,500	<0.00020	<0.0010	<0.0010	<0.0010	0.062	0.0062		
	15-Nov-16	QB0518	<0.00010	110	2.7	440	<0.00020	<0.0010	<0.0010	<0.0010	0.037	<0.0030		
QA/QC	Field Blank	16-Nov-16	QB0519	<0.00010	74	2.1	320	<0.00020	0.0024	<0.0010	<0.0010	0.024	0.023	
		16-Nov-16	QB0520	<0.00010	1,800	9.5	4,900	0.00026	<0.0010	0.0014	<0.0010	0.16	0.0072	
QA/QC	Trip Blank	28-Oct-16	PX2262	<0.00010	<0.50	<0.020	<0.20	<0.00020	<0.0010	<0.0010	<0.0010	<0.00010	<0.0030	
		28-Oct-16	PX2263	<0.00010	<0.50	<0.020	<0.20	<0.00020	<0.0010	<0.0010	<0.0010	<0.00010	<0.0030	

Notes:
(a) Health Canada Guidelines for Canadian Drinking Water Quality, October 2014.
(b) Federal Contaminated Sites Action Plan (FCSAP) Federal Interim Groundwater Quality Guidelines (FIGQs) for Federal Contaminated Sites. Table 1: Tier 2 Guidelines for fine-grained soil and agricultural land use, with the Marine Life pathway excluded, June 2016, version 4.
FCSAP guidelines for aluminum (considering pH), and cadmium, copper, lead and nickel (considering hardness) were determined based on FCSAP guidance, including reference to CCME calculations. For aluminum, pH >6.5 at the Site, as such guideline of 100 ug/L was used. For hardness dependent parameters, CCME calculations were conducted using the CCME online calculator using the minimum hardness of all groundwater quality samples collected at the Site (i.e., 280 mg/L). Source: Canadian Council of Ministers of the Environment (CCME) Canadian Water Quality Guidelines for the Protection of Freshwater Aquatic Life (FAL), current to 2017.
RDL - reported detection limit
mg/L - milligrams per litre
N/A - not available
< - less than
ng - no guideline
QA/QC - Quality Assurance Quality Control
BOLD indicates samples in exceedance of applied guideline.
BOLD indicates the reportable detection limit exceeded the applied guideline
Table should be read in conjunction with accompanying report.

Table A.9
Summary of Current and Historic Groundwater Analytical Results - Polycyclic Aromatic Hydrocarbons
Bar U Ranch National Historic Site, Alberta
Public Works and Government Services Canada

Reference or Exposure Location	Monitoring Well	Sample Collection Date	Maxxam Sample ID	Acenaphthene	Acenaphthylene	Acridine	Anthracene	Benzo[a]anthracene	Benzo [b,j] fluoranthene
				mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
Units				mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
2016 Reportable Detection Limit				0.0001	0.0001	0.0002	0.00001	0.0000085	0.0000085
Health Canada ^(a)				ng	ng	ng	ng	ng	ng
FCSAP ^(b)				0.0058	0.046	ng	0.000012	0.000018	0.00048
Exposure	MW1	20-Oct-04	N/A	<0.00005	<0.00005	N/A	0.00002	<0.000010	0.000015
		28-Nov-08	N/A	<0.00001	N/A	<0.00001	<0.000010	<0.000010	<0.000010
		16-Dec-14	LJ9563	<0.00010	<0.00010	<0.00020	<0.000010	<0.0000085	<0.0000085
		09-Jul-15	MQ2964	<0.00010	<0.00010	<0.00020	<0.000010	<0.0000085	<0.0000085
		09-Jul-15	MQ2961 (Dup: DUP15-01)	<0.00010	<0.00010	<0.00020	<0.000010	<0.0000085	<0.0000085
	MW2	28-Oct-16	PX2261	<0.00010	<0.00010	<0.00020	<0.000010	<0.0000085	<0.0000085
		03-Nov-06	N/A	<0.00001	<0.00001	N/A	<0.000010	<0.000010	<0.000010
		16-Dec-14	LJ9567	<0.00025	<0.00025	<0.00050	<0.000025	<0.000021	<0.000021
	MW3	13-Jul-15	MQ5586	<0.00010	<0.00010	<0.00020	<0.000010	<0.0000085	<0.0000085
		27-Oct-16	PX2253	<0.00010	<0.00010	<0.00020	<0.000010	<0.0000085	<0.0000085
		28-Nov-08	N/A	<0.00001	N/A	<0.00001	<0.000010	<0.000010	<0.000010
	MW4	18-Dec-14	LK1840	<0.00010	<0.00010	<0.00020	<0.000010	<0.0000085	<0.0000085
		13-Jul-15	MQ5585	<0.00010	<0.00010	<0.00020	<0.000010	<0.0000085	<0.0000085
		28-Oct-16	PX2255	<0.00010	<0.00010	<0.00020	<0.000010	<0.0000085	<0.0000085
	MW5	20-Oct-04	N/A	<0.00020	<0.00020	N/A	<0.00020	<0.00020	<0.00020
		28-Nov-08	N/A	<0.00001	N/A	<0.00001	<0.000010	<0.000010	<0.000010
	MW6	13-Jul-15	MQ5587	<0.00010	<0.00010	<0.00020	<0.000010	<0.0000085	<0.0000085
		20-Oct-04	N/A	<0.00005	<0.00005	N/A	0.000012	0.00002	0.000051
		28-Nov-08	N/A	<0.00001	N/A	<0.00001	<0.000010	<0.000010	<0.000010
		18-Dec-14	LK1839	<0.00010	<0.00010	<0.00020	0.000014	<0.0000085	<0.0000085
MW6	13-Jul-15	MQ5588	<0.00010	<0.00010	<0.00020	<0.000010	<0.0000085	<0.0000085	
	28-Oct-16	PX2256	<0.00010	<0.00010	<0.00020	<0.000010	<0.0000085	<0.0000085	
QA/QC	MWDI (Duplicate of MW6)	28-Oct-16	PX2260	<0.00010	<0.00010	<0.00020	<0.000010	<0.0000085	
Exposure	MW7	16-Dec-14	LJ9566	<0.00010	<0.00010	<0.00020	<0.000010	<0.0000085	<0.0000085
		09-Jul-15	MQ2965	<0.00010	<0.00010	<0.00020	<0.000010	<0.0000085	<0.0000085
		27-Oct-16	PX2252	<0.00010	<0.00010	<0.00020	<0.000010	<0.0000085	<0.0000085
	MW8	31-Oct-06	N/A	<0.00001	<0.00001	N/A	<0.000010	<0.000010	<0.000010
		16-Dec-14	LJ9564	<0.00010	<0.00010	<0.00020	<0.000010	<0.0000085	<0.0000085
		09-Jul-15	MQ2966	<0.00010	<0.00010	<0.00020	<0.000010	<0.0000085	<0.0000085
	MW9	28-Oct-16	PX2259	<0.00010	<0.00010	<0.00020	<0.000010	<0.0000085	<0.0000085
		16-Dec-14	LJ9565	<0.00010	<0.00010	<0.00020	<0.000010	<0.0000085	<0.0000085
		09-Jul-15	MQ2967	<0.00010	<0.00010	<0.00020	<0.000010	<0.0000085	<0.0000085
	MW12	28-Oct-16	PX2258	<0.00010	<0.00010	<0.00020	<0.000010	<0.0000085	<0.0000085
		31-Oct-06	N/A	<0.00001	<0.00001	N/A	<0.000010	<0.000010	<0.000010
		18-Dec-14	LK1838	<0.00025	<0.00025	<0.00050	<0.000025	<0.000021	<0.000021
		09-Jul-15	MQ2968	<0.00010	<0.00010	<0.00020	<0.000010	<0.0000085	0.000026
	MW14	27-Oct-16	PX2254	<0.00010	<0.00010	<0.00020	<0.000010	<0.0000085	<0.0000085
28-Nov-08		N/A	0.00002	N/A	<0.00001	<0.000010	<0.000010	0.00002	
28-Nov-08		N/A	<0.00001	N/A	<0.00001	<0.000010	<0.000010	<0.000010	
28-Oct-16		PX2257	<0.00010	<0.00010	<0.00020	<0.000010	<0.0000085	<0.0000085	
28-Oct-16		PX2257	<0.00010	<0.00010	<0.00020	<0.000010	<0.0000085	<0.0000085	
Reference	GMW18	27-Nov-15	NS8667	<0.00010	<0.00010	<0.00020	<0.000010	<0.0000085	<0.0000085
		27-Oct-16	PX2251	<0.00010	<0.00010	<0.00020	<0.000010	<0.0000085	<0.0000085
	GMW19	15-Nov-16	QB0518	<0.00010	<0.00010	<0.00020	<0.000010	<0.0000085	<0.0000085
	GMW20	16-Nov-16	QB0519	<0.00010	<0.00010	<0.00020	<0.000010	<0.0000085	<0.0000085
QA/QC	Trip Blank	28-Oct-16	PX2262	<0.00010	<0.00010	<0.00020	<0.000010	<0.0000085	<0.0000085
	MWD1 Field Blank	28-Oct-16	PX2263	<0.00010	<0.00010	<0.00020	<0.000010	<0.0000085	<0.0000085

Notes:
(a) Health Canada Guidelines for Canadian Drinking Water Quality, October 2014.
(b) Federal Contaminated Sites Action Plan (FCSAP) Federal Interim Groundwater Quality Guidelines (FIGQGs) for Federal Contaminated Sites. Table 1: Tier 2 Guidelines for fine-grained soil and agricultural land use, with the Marine Life pathway excluded, June 2016, version 4.
RDL - reported detection limit
mg/L - milligrams per litre
N/A - not applicable
< - less than
ng - no guideline
QA/QC - Quality Assurance Quality Control
BOLD indicates samples in exceedance of applied guideline.
BOLD indicates the reportable detection limit exceeded the applied guidelines.
Table should be read in conjunction with accompanying report.

Table A.9
Summary of Current and Historic Groundwater Analytical Results - Polycyclic Aromatic Hydrocarb
Bar U Ranch National Historic Site, Alberta
Public Works and Government Services Canada

Reference or Exposure Location	Monitoring Well	Sample Collection Date	Maxxam Sample ID	Parameters					
				Benzo[k]fluoranthene	Benzo[g,h,i]perylene	Benzo[c]phenanthrene	Benzo[a]pyrene	Benzo[e]pyrene	Chrysene
Units				mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
2016 Reportable Detection Limit				0.000085	0.000085	0.00005	0.000075	0.00005	0.000085
Health Canada ^(a)				ng	ng	ng	0.00001	ng	ng
FCSAP ^(b)				0.00048	0.00021	ng	0.000017	ng	0.0014
Exposure	MW1	20-Oct-04	N/A	<0.000010	0.000013	N/A	0.00001	N/A	0.000017
		28-Nov-08	N/A	<0.000010	N/A	N/A	<0.000010	N/A	<0.000010
		16-Dec-14	LJ9563	<0.000085	<0.000085	<0.000050	<0.000075	<0.000050	<0.000085
		09-Jul-15	MQ2964	<0.000085	<0.000085	<0.000050	<0.000075	<0.000050	<0.000085
		09-Jul-15	MQ2961 (Dup: DUP15-01)	<0.000085	<0.000085	<0.000050	<0.000075	<0.000050	<0.000085
	MW2	28-Oct-16	PX2261	<0.000085	<0.000085	<0.000050	<0.000075	<0.000050	<0.000085
		03-Nov-06	N/A	<0.000010	<0.000010	<0.000010	<0.000010	N/A	<0.000010
		16-Dec-14	LJ9567	<0.000021	<0.000021	<0.00013	<0.000019	<0.00013	<0.000021
	MW3	13-Jul-15	MQ5586	<0.000085	<0.000085	<0.000050	<0.000075	<0.000050	<0.000085
		27-Oct-16	PX2253	<0.000085	<0.000085	<0.000050	<0.000075	<0.000050	<0.000085
		28-Nov-08	N/A	<0.000010	N/A	N/A	<0.000010	N/A	<0.000010
	MW4	18-Dec-14	LK1840	<0.000085	<0.000085	<0.000050	<0.000075	<0.000050	<0.000085
		13-Jul-15	MQ5585	<0.000085	<0.000085	<0.000050	<0.000075	<0.000050	<0.000085
		28-Oct-16	PX2255	<0.000085	<0.000085	<0.000050	<0.000075	<0.000050	<0.000085
	MW5	20-Oct-04	N/A	<0.00020	<0.00020	N/A	0.000007	N/A	<0.00020
		28-Nov-08	N/A	<0.000010	N/A	N/A	<0.000010	N/A	<0.000010
	MW6	13-Jul-15	MQ5587	<0.000085	<0.000085	<0.000050	<0.000075	<0.000050	<0.000085
		20-Oct-04	N/A	0.000013	0.000038	N/A	0.000024	N/A	0.000078
		28-Nov-08	N/A	<0.000010	N/A	N/A	<0.000010	N/A	<0.000010
		18-Dec-14	LK1839	<0.000085	<0.000085	<0.000050	<0.000075	<0.000050	0.000011
MW6	13-Jul-15	MQ5588	<0.000085	<0.000085	<0.000050	<0.000075	<0.000050	<0.000085	
	28-Oct-16	PX2256	0.000019	<0.000085	<0.000050	<0.000075	<0.000050	<0.000085	
QA/QC	MWDI (Duplicate of MW6)	28-Oct-16	PX2260	<0.000085	<0.000085	<0.000050	<0.000075	<0.000050	<0.000085
Exposure	MW7	16-Dec-14	LJ9566	<0.000085	<0.000085	<0.000050	<0.000075	<0.000050	<0.000085
		09-Jul-15	MQ2965	<0.000085	<0.000085	<0.000050	<0.000075	<0.000050	<0.000085
		27-Oct-16	PX2252	<0.000085	<0.000085	<0.000050	<0.000075	<0.000050	<0.000085
	MW8	31-Oct-06	N/A	<0.000010	<0.000010	<0.000010	<0.000010	N/A	<0.000010
		16-Dec-14	LJ9564	<0.000085	<0.000085	<0.000050	<0.000075	<0.000050	<0.000085
		09-Jul-15	MQ2966	<0.000085	<0.000085	<0.000050	<0.000075	<0.000050	<0.000085
	MW9	28-Oct-16	PX2259	<0.000085	<0.000085	<0.000050	<0.000075	<0.000050	<0.000085
		16-Dec-14	LJ9565	<0.000085	<0.000085	<0.000050	<0.000075	<0.000050	<0.000085
		09-Jul-15	MQ2967	<0.000085	<0.000085	<0.000050	<0.000075	<0.000050	<0.000085
	MW12	28-Oct-16	PX2258	<0.000085	<0.000085	<0.000050	<0.000075	<0.000050	<0.000085
		31-Oct-06	N/A	<0.000010	<0.000010	<0.000010	<0.000010	N/A	<0.000010
		18-Dec-14	LK1838	<0.000021	<0.000021	<0.00013	<0.000019	<0.00013	<0.000021
		09-Jul-15	MQ2968	0.000013	0.000015	<0.000050	0.000012	<0.000050	0.000014
	MW14	27-Oct-16	PX2254	<0.000085	<0.000085	<0.000050	<0.000075	<0.000050	<0.000085
		28-Nov-08	N/A	<0.000010	N/A	N/A	0.00002	N/A	0.00002
MW16	28-Nov-08	N/A	<0.000010	N/A	N/A	<0.000010	N/A	<0.000010	
	28-Oct-16	PX2257	<0.000085	<0.000085	<0.000050	<0.000075	<0.000050	<0.000085	
Reference	GMW18	27-Nov-15	NS8667	<0.000085	<0.000085	<0.000050	<0.000075	<0.000050	<0.000085
		27-Oct-16	PX2251	<0.000085	<0.000085	<0.000050	<0.000075	<0.000050	<0.000085
	GMW19	15-Nov-16	QB0518	<0.000085	<0.000085	<0.000050	<0.000075	<0.000050	<0.000085
	GMW20	16-Nov-16	QB0519	<0.000085	<0.000085	<0.000050	<0.000075	<0.000050	<0.000085
	GMW21	16-Nov-16	QB0520	<0.000085	<0.000085	<0.000050	<0.000075	<0.000050	<0.000085
QA/QC	Trip Blank	28-Oct-16	PX2262	<0.000085	<0.000085	<0.000050	<0.000075	<0.000050	<0.000085
	MWD1 Field Blank	28-Oct-16	PX2263	<0.000085	<0.000085	<0.000050	<0.000075	<0.000050	<0.000085

Notes:
(a) Health Canada Guidelines for Canadian Drinking Water Quality, October 2014.
(b) Federal Contaminated Sites Action Plan (FCSAP) Federal Interim Groundwater Quality Guidelines (FIGQGs) for Federal Contaminated Sites. Table 1: Tier 2 Guidelines for fine-grained soil and agricultural land use, with the Marine Life pathway excluded, June 2016, version 4.
RDL - reported detection limit
mg/L - milligrams per litre
N/A - not applicable
< - less than
ng - no guideline
QA/QC - Quality Assurance Quality Control
BOLD indicates samples in exceedance of applied guideline.
BOLD indicates the reportable detection limit exceeded the applied guidelines.
Table should be read in conjunction with accompanying report.

Table A.9
Summary of Current and Historic Groundwater Analytical Results - Polycyclic Aromatic Hydrocarb
Bar U Ranch National Historic Site, Alberta
Public Works and Government Services Canada

Reference or Exposure Location	Monitoring Well	Sample Collection Date	Maxxam Sample ID	Dibenz[a,h]anthracene	Fluoranthene	Fluorene	Indeno[1,2,3-cd]pyrene	2-Methylnaphthalene	Naphthalene
				mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
Units				mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
2016 Reportable Detection Limit				0.000075	0.00001	0.00005	0.0000085	0.0001	0.0001
Health Canada ^(a)				ng	ng	ng	ng	ng	ng
FCSAP ^(b)				0.00028	0.00004	0.003	0.00023	0.18	0.0011
Exposure	MW1	20-Oct-04	N/A	<0.000010	0.000015	<0.000050	<0.000010	N/A	0.000051
		28-Nov-08	N/A	<0.000010	<0.000010	<0.000010	<0.000010	N/A	<0.00001
		16-Dec-14	LJ9563	<0.000075	<0.000010	<0.000050	<0.000085	N/A	<0.00010
		09-Jul-15	MQ2964	<0.000075	<0.000010	<0.000050	<0.000085	<0.00010	<0.00010
		09-Jul-15	MQ2961 (Dup: DUP15-01)	<0.000075	<0.000010	<0.000050	<0.000085	<0.00010	<0.00010
	28-Oct-16	PX2261	<0.000075	<0.000010	<0.000050	<0.000085	<0.00010	<0.00010	
	MW2	03-Nov-06	N/A	<0.000010	<0.000010	<0.000010	<0.000010	N/A	<0.00001
		16-Dec-14	LJ9567	<0.000019	0.000037	<0.00013	<0.000021	N/A	<0.00025
		13-Jul-15	MQ5586	<0.000075	<0.000010	<0.000050	<0.000085	<0.00010	<0.00010
	MW3	27-Oct-16	PX2253	<0.000075	0.000018	<0.000050	<0.000085	<0.00010	<0.00010
		28-Nov-08	N/A	<0.000010	<0.000010	<0.000010	<0.000010	N/A	<0.00001
		18-Dec-14	LK1840	<0.000075	0.000043	<0.000050	<0.000085	N/A	<0.00010
	MW4	13-Jul-15	MQ5585	<0.000075	<0.000010	<0.000050	<0.000085	<0.00010	<0.00010
		28-Oct-16	PX2255	<0.000075	<0.000010	<0.000050	<0.000085	<0.00010	<0.00010
		20-Oct-04	N/A	<0.00020	<0.00020	<0.00020	<0.00020	N/A	<0.00020
	MW5	28-Nov-08	N/A	<0.000010	<0.000010	<0.000010	<0.000010	N/A	<0.00001
		13-Jul-15	MQ5587	<0.000075	<0.000010	<0.000050	<0.000085	<0.00010	<0.00010
	MW6	20-Oct-04	N/A	0.000012	0.000053	0.000099	0.000015	N/A	0.000178
		28-Nov-08	N/A	<0.000010	<0.000010	<0.000010	<0.000010	N/A	0.00003
		18-Dec-14	LK1839	<0.000075	0.000062	0.000071	<0.000085	N/A	<0.00010
13-Jul-15		MQ5588	<0.000075	<0.000010	<0.000050	<0.000085	<0.00010	<0.00010	
MW7	28-Oct-16	PX2256	<0.000075	<0.000010	<0.000050	<0.000085	<0.00010	<0.00010	
	28-Oct-16	PX2260	<0.000075	<0.000010	<0.000050	<0.000085	<0.00010	<0.00010	
Exposure	MW7	16-Dec-14	LJ9566	<0.000075	<0.000010	<0.000050	<0.000085	N/A	<0.00010
		09-Jul-15	MQ2965	<0.000075	<0.000010	<0.000050	<0.000085	<0.00010	<0.00010
		27-Oct-16	PX2252	<0.000075	0.000018	<0.000050	<0.000085	<0.00010	<0.00010
	MW8	31-Oct-06	N/A	<0.000010	<0.000010	<0.000010	<0.000010	N/A	<0.00001
		16-Dec-14	LJ9564	<0.000075	0.000021	<0.000050	<0.000085	N/A	<0.00010
		09-Jul-15	MQ2966	<0.000075	0.000012	<0.000050	<0.000085	<0.00010	<0.00010
	MW9	28-Oct-16	PX2259	<0.000075	0.000018	<0.000050	<0.000085	<0.00010	<0.00010
		16-Dec-14	LJ9565	<0.000075	<0.000010	<0.000050	<0.000085	N/A	<0.00010
		09-Jul-15	MQ2967	<0.000075	<0.000010	<0.000050	<0.000085	<0.00010	<0.00010
	MW12	28-Oct-16	PX2258	<0.000075	0.000018	<0.000050	<0.000085	<0.00010	<0.00010
		31-Oct-06	N/A	<0.000010	<0.000010	<0.000010	<0.000010	N/A	<0.00001
		18-Dec-14	LK1838	<0.000019	<0.000025	<0.00013	<0.000021	N/A	<0.00025
		09-Jul-15	MQ2968	0.000012	0.000023	<0.000050	0.000013	<0.00010	<0.00010
	MW14	27-Oct-16	PX2254	<0.000075	0.000018	<0.000050	<0.000085	<0.00010	<0.00010
	MW16	28-Nov-08	N/A	<0.000010	0.00003	0.00004	<0.000010	N/A	0.00003
MW17	28-Nov-08	N/A	<0.000010	<0.000010	0.00002	<0.000010	N/A	0.00002	
Reference	GMW18	28-Oct-16	PX2257	<0.000075	0.000018	<0.000050	<0.000085	<0.00010	<0.00010
		27-Nov-15	NS8667	<0.000075	<0.000010	<0.000050	<0.000085	<0.00010	<0.00010
	GMW19	15-Nov-16	QB0518	<0.000075	0.000018	<0.000050	<0.000085	<0.00010	<0.00010
	GMW20	16-Nov-16	QB0519	<0.000075	0.000018	<0.000050	<0.000085	<0.00010	<0.00010
	GMW21	16-Nov-16	QB0520	<0.000075	0.000018	<0.000050	<0.000085	<0.00010	<0.00010
QA/QC	Trip Blank	28-Oct-16	PX2262	<0.000075	<0.000010	<0.000050	<0.000085	<0.00010	<0.00010
	MWD1 Field Blank	28-Oct-16	PX2263	<0.000075	<0.000010	<0.000050	<0.000085	<0.00010	<0.00010

Notes:
(a) Health Canada Guidelines for Canadian Drinking Water Quality, October 2014.
(b) Federal Contaminated Sites Action Plan (FCSAP) Federal Interim Groundwater Quality Guidelines (FIGQGs) for Federal Contaminated Sites. Table 1: Tier 2 Guidelines for fine-grained soil and agricultural land use, with the Marine Life pathway excluded, June 2016, version 4.
RDL - reported detection limit
mg/L - milligrams per litre
N/A - not applicable
< - less than
ng - no guideline
QA/QC - Quality Assurance Quality Control
BOLD indicates samples in exceedance of applied guideline.
BOLD indicates the reportable detection limit exceeded the applied guidelines.
Table should be read in conjunction with accompanying report.

Table A.9
Summary of Current and Historic Groundwater Analytical Results - Polycyclic Aromatic Hydrocarb
Bar U Ranch National Historic Site, Alberta
Public Works and Government Services Canada

Reference or Exposure Location	Monitoring Well	Sample Collection Date	Maxxam Sample ID	Perylene	Phenanthrene	Pyrene	Quinoline	B(a)P Equivalency
				mg/L	mg/L	mg/L	mg/L	mg/L
Units				mg/L	mg/L	mg/L	mg/L	mg/L
2016 Reportable Detection Limit				0.00005	0.00005	0.00002	0.0002	0.00001
Health Canada ^(a)				ng	ng	ng	ng	ng
FCSAP ^(b)				ng	0.0004	0.000025	0.0034	ng
Exposure	MW1	20-Oct-04	N/A	N/A	0.000064	0.000036	N/A	0.000012
		28-Nov-08	N/A	N/A	0.00003	<0.000010	<0.00001	N/A
		16-Dec-14	LJ9563	<0.000050	<0.000050	<0.000020	<0.00020	<0.000010
		09-Jul-15	MQ2964	<0.000050	<0.000050	<0.000020	<0.00020	<0.000010
		09-Jul-15	MQ2961 (Dup: DUP15-01)	<0.000050	<0.000050	<0.000020	<0.00020	<0.000010
	MW2	28-Oct-16	PX2261	<0.000050	<0.000050	<0.000020	<0.00020	<0.000010
		03-Nov-06	N/A	N/A	<0.000010	<0.000010	N/A	<0.000030
		16-Dec-14	LJ9567	<0.00013	<0.00013	0.000054	<0.00050	0.000023
	MW3	13-Jul-15	MQ5586	<0.000050	<0.000050	<0.000020	<0.00020	<0.000010
		27-Oct-16	PX2253	<0.000050	<0.000050	0.000028	<0.00020	<0.000010
		28-Nov-08	N/A	N/A	<0.000010	<0.000010	<0.00001	N/A
	MW4	18-Dec-14	LK1840	<0.000050	<0.000050	0.000042	<0.00020	<0.000010
		13-Jul-15	MQ5585	<0.000050	<0.000050	<0.000020	<0.00020	<0.000010
		28-Oct-16	PX2255	<0.000050	<0.000050	<0.000020	<0.00020	<0.000010
	MW5	20-Oct-04	N/A	N/A	<0.00020	<0.00020	N/A	N/A
		28-Nov-08	N/A	N/A	<0.000010	<0.000010	<0.00001	N/A
	MW6	13-Jul-15	MQ5587	<0.000050	<0.000050	<0.000020	<0.00020	<0.000010
		20-Oct-04	N/A	N/A	0.000346	0.000116	N/A	N/A
		28-Nov-08	N/A	N/A	0.00003	<0.000010	<0.00001	N/A
		18-Dec-14	LK1839	<0.000050	0.00019	0.000088	<0.00020	<0.000010
MW6	13-Jul-15	MQ5588	<0.000050	<0.000050	<0.000020	<0.00020	<0.000010	
	28-Oct-16	PX2256	<0.000050	<0.000050	<0.000020	<0.00020	0.000011	
QA/QC	MWD1 (Duplicate of MW6)	28-Oct-16	PX2260	<0.000050	<0.000050	<0.000020	<0.00020	<0.000010
Exposure	MW7	16-Dec-14	LJ9566	<0.000050	<0.000050	<0.000020	<0.00020	<0.000010
		09-Jul-15	MQ2965	<0.000050	<0.000050	<0.000020	<0.00020	<0.000010
		27-Oct-16	PX2252	<0.000050	<0.000050	<0.000020	<0.00020	<0.000010
	MW8	31-Oct-06	N/A	N/A	<0.000010	<0.000010	N/A	<0.000030
		16-Dec-14	LJ9564	<0.000050	<0.000050	0.000041	<0.00020	<0.000010
		09-Jul-15	MQ2966	<0.000050	<0.000050	0.000037	<0.00020	<0.000010
	MW9	28-Oct-16	PX2259	<0.000050	<0.000050	<0.000020	<0.00020	<0.000010
		16-Dec-14	LJ9565	<0.000050	<0.000050	0.000032	<0.00020	<0.000010
		09-Jul-15	MQ2967	<0.000050	<0.000050	<0.000020	<0.00020	<0.000010
	MW12	28-Oct-16	PX2258	<0.000050	<0.000050	<0.000020	<0.00020	<0.000010
		31-Oct-06	N/A	N/A	0.00002	<0.000010	N/A	<0.000030
		18-Dec-14	LK1838	<0.00013	0.00015	0.000064	<0.00050	0.000023
		09-Jul-15	MQ2968	<0.000050	0.000091	0.000052	<0.00020	<0.000010
	MW14	27-Oct-16	PX2254	<0.000050	<0.000050	<0.000020	<0.00020	<0.000010
28-Nov-08		N/A	N/A	0.00012	0.00007	<0.00001	N/A	
MW16	28-Nov-08	N/A	N/A	0.00003	0.00003	<0.00001	N/A	
	28-Oct-16	PX2257	<0.000050	<0.000050	<0.000020	<0.00020	<0.000010	
Reference	GMW18	27-Nov-15	NS8667	<0.000050	<0.000050	<0.000020	<0.00020	<0.000010
		27-Oct-16	PX2251	<0.000050	<0.000050	<0.000020	<0.00020	<0.000010
	GMW19	15-Nov-16	QB0518	<0.000050	<0.000050	<0.000020	<0.00020	<0.000010
	GMW20	16-Nov-16	QB0519	<0.000050	<0.000050	<0.000020	<0.00020	<0.000010
	GMW21	16-Nov-16	QB0520	<0.000050	<0.000050	<0.000020	<0.00020	<0.000010
QA/QC	Trip Blank	28-Oct-16	PX2262	<0.000050	<0.000050	<0.000020	<0.00020	<0.000010
	MWD1 Field Blank	28-Oct-16	PX2263	<0.000050	<0.000050	<0.000020	<0.00020	<0.000010

Notes:
(a) Health Canada Guidelines for Canadian Drinking Water Quality, October 2014.
(b) Federal Contaminated Sites Action Plan (FCSAP) Federal Interim Groundwater Quality Guidelines (FIGQGs) for Federal Contaminated Sites. Table 1: Tier 2 Guidelines for fine-grained soil and agricultural land use, with the Marine Life pathway excluded, June 2016, version 4.
RDL - reported detection limit
mg/L - milligrams per litre
N/A - not applicable
< - less than
ng - no guideline
QA/QC - Quality Assurance Quality Control
BOLD indicates samples in exceedance of applied guideline.
BOLD indicates the reportable detection limit exceeded the applied guidelines.
Table should be read in conjunction with accompanying report.

Table A.10
Summary of Current and Historic Surface Water Analytical Results - Routine Chemistry Parameters
Bar U Ranch National Historic Site, Alberta
Public Works and Government Services Canada

Reference or Exposure Location	Sample Location	Sample Collection Date	Maxxam Sample ID	Parameters																				
				Hardness (CaCO3)	Dissolved Nitrate (NO3)	Nitrate plus Nitrite (N)	Dissolved Nitrite (NO2)	Total Dissolved Solids	Conductivity	pH	Alkalinity (PP as CaCO3)	Alkalinity (Total as CaCO3)	Bicarbonate (HCO3)	Carbonate (CO3)	Hydroxide (OH)	Dissolved Sulphate (SO4)	Dissolved Chloride (Cl)	Dissolved Nitrite (N)	Dissolved Nitrate (N)	Dissolved Iron (Fe)	Dissolved Magnesium (Mg)	Dissolved Manganese (Mn)	Dissolved Potassium (K)	Dissolved Sodium (Na)
Units				mg/L	mg/L	mg/L	mg/L	mg/L	uS/cm	pH	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	
2016 Reportable Detection Limit				0.5	0.044	0.02	0.033	10	1	N/A	0.5	0.5	0.5	0.5	0.5	1	1	0.01	0.01	0.06	0.2	0.004	0.3	0.5
CCME FAL ^(a)				ng	13	ng	0.06	ng	ng	6.5 - 9	ng	ng	ng	ng	ng	120	ng	ng	0.3	ng	ng	ng	ng	
CCME AG ^(b)				ng	ng	100	10	3,000	ng	ng	ng	ng	ng	ng	1,000	355	ng	ng	5	ng	ng	ng	ng	
Reference	SW15-01 (Upstream)	27-Nov-15	NS8665	250	0.17	0.038	<0.033	260	480	8.24	< 0.50	210	260	< 0.50	< 0.50	35	1.1	<0.010	0.038	< 0.060	17	< 0.0040	N/A	N/A
Exposure	SW15-02 (Downstream)	27-Nov-15	NS8666	240	0.19	0.043	<0.033	260	480	8.23	< 0.50	220	260	< 0.50	< 0.50	35	1.1	<0.010	0.043	< 0.060	17	< 0.0040	N/A	N/A
Reference	SW16-01-01	26-Oct-16	PW6554	220	0.64	0.14	< 0.033	240	410	8.24	< 0.50	200	250	< 0.50	< 0.50	28	1.5	< 0.010	0.14	< 0.060	13	< 0.0040	0.91	5.3
Reference	SW16-01-02	26-Oct-16	PW6555	220	< 0.044	< 0.020	< 0.033	240	410	8.29	< 0.50	210	250	< 0.50	< 0.50	29	1	< 0.010	< 0.010	< 0.060	13	< 0.0040	0.9	5.3
Reference	SW16-01-03	26-Oct-16	PW6556	220	0.086	< 0.020	< 0.033	240	410	8.26	< 0.50	200	250	< 0.50	< 0.50	28	1.6	< 0.010	0.019	< 0.060	13	< 0.0040	0.91	5.3
Reference	SW16-01-04	26-Oct-16	PW6557	230	< 0.044	< 0.020	< 0.033	240	410	8.23	< 0.50	200	250	< 0.50	< 0.50	28	2	< 0.010	< 0.010	< 0.060	14	< 0.0040	0.92	5.5
Exposure	SW16-02-01	26-Oct-16	PW6558	220	< 0.044	< 0.020	< 0.033	240	410	8.19	< 0.50	210	250	< 0.50	< 0.50	29	1.3	< 0.010	< 0.010	< 0.060	13	< 0.0040	0.96	5.3
Exposure	SW16-02-02	26-Oct-16	PW6559	220	0.07	< 0.020	< 0.033	230	410	8.25	< 0.50	200	240	< 0.50	< 0.50	28	1.2	< 0.010	0.016	< 0.060	13	< 0.0040	0.92	5.4
Exposure	SW16-02-03	26-Oct-16	PW6560	220	< 0.044	< 0.020	< 0.033	240	410	8.22	< 0.50	210	250	< 0.50	< 0.50	29	1.3	< 0.010	< 0.010	< 0.060	13	< 0.0040	0.91	5.1
Exposure	SW16-02-04	26-Oct-16	PW6561	220	< 0.044	< 0.020	< 0.033	240	410	8.21	< 0.50	200	250	< 0.50	< 0.50	28	1.7	< 0.010	< 0.010	< 0.060	13	< 0.0040	0.96	5.3
Reference	SW16-03-01	26-Oct-16	PW6562	220	< 0.044	< 0.020	< 0.033	240	410	8.24	< 0.50	200	250	< 0.50	< 0.50	28	1.6	< 0.010	< 0.010	< 0.060	13	< 0.0040	0.91	5.4
Reference	SW16-03-02	26-Oct-16	PW6569	220	< 0.044	< 0.020	< 0.033	240	410	8.26	< 0.50	200	250	< 0.50	< 0.50	28	1.4	< 0.010	< 0.010	< 0.060	13	< 0.0040	0.91	5.4
Reference	SW16-03-03	26-Oct-16	PW6570	220	< 0.044	< 0.020	< 0.033	230	410	8.28	< 0.50	200	250	< 0.50	< 0.50	26	1.5	< 0.010	< 0.010	< 0.060	13	< 0.0040	0.86	5.3
Reference	SW16-04-01	26-Oct-16	PW6571	210	< 0.044	< 0.020	< 0.033	240	410	8.21	< 0.50	200	250	< 0.50	< 0.50	30	1.3	< 0.010	< 0.010	< 0.060	13	< 0.0040	0.88	5.1
Reference	SW16-04-02	26-Oct-16	PW6572	220	< 0.044	< 0.020	< 0.033	240	410	8.25	< 0.50	200	240	< 0.50	< 0.50	28	1.2	< 0.010	< 0.010	< 0.060	14	< 0.0040	0.98	5.6
Reference	SW16-05-01	26-Oct-16	PW6573	220	< 0.044	< 0.020	< 0.033	240	410	8.29	< 0.50	200	250	< 0.50	< 0.50	28	1.9	< 0.010	< 0.010	< 0.060	13	< 0.0040	0.95	5.5
Reference	SW16-05-02	26-Oct-16	PW6574	220	< 0.044	< 0.020	< 0.033	240	410	8.28	< 0.50	200	240	< 0.50	< 0.50	28	1.1	< 0.010	< 0.010	< 0.060	14	< 0.0040	0.96	5.6
Exposure	SW16-06-01	26-Oct-16	PW6575	230	< 0.044	< 0.020	< 0.033	240	410	8.27	< 0.50	200	250	< 0.50	< 0.50	28	1.2	< 0.010	< 0.010	< 0.060	14	< 0.0040	1	5.6
Exposure	SW16-06-02	26-Oct-16	PW6576	220	< 0.044	< 0.020	< 0.033	230	410	8.3	< 0.50	190	240	< 0.50	< 0.50	27	1.4	< 0.010	< 0.010	< 0.060	14	< 0.0040	0.99	5.5
Exposure	SW16-06-03	26-Oct-16	PW6577	220	< 0.044	< 0.020	< 0.033	240	410	8.29	< 0.50	210	250	< 0.50	< 0.50	28	1.1	< 0.010	< 0.010	< 0.060	14	< 0.0040	1	5.6
Exposure	SW16-07-01	26-Oct-16	PW6578	220	0.051	< 0.020	< 0.033	240	410	8.29	< 0.50	210	250	< 0.50	< 0.50	28	1	< 0.010	0.012	< 0.060	13	< 0.0040	0.97	5.6
Exposure	SW16-07-02	26-Oct-16	PW6584	230	< 0.044	< 0.020	0.04	270	410	8.27	< 0.50	200	250	< 0.50	< 0.50	56	1.1	0.012	< 0.010	< 0.060	14	< 0.0040	1	5.7
Exposure	SW16-08-01	26-Oct-16	PW6585	220	< 0.044	< 0.020	< 0.033	240	410	8.25	< 0.50	210	250	< 0.50	< 0.50	26	<1.0	< 0.010	< 0.010	< 0.060	13	< 0.0040	0.97	5.5
Exposure	SW16-08-02	26-Oct-16	PW6586	230	< 0.044	< 0.020	< 0.033	240	410	8.28	< 0.50	200	250	< 0.50	< 0.50	28	1.5	< 0.010	< 0.010	< 0.060	14	< 0.0040	0.97	5.4

Notes:
 (a) Canadian Council of Ministers of the Environment (CCME) Canadian Water Quality Guidelines for the Protection of Freshwater Aquatic Life (FAL), current to 2017.
 (b) Canadian Council of Ministers of the Environment (CCME) Canadian Water Quality Guidelines for the Protection of Agricultural (Ag) Water Uses (Trigation and Livestock Water), current to 2017.
 CCME AG guideline for chloride was based on foliar damage for crops that were considered likely to be produced in this climate zone (including alfalfa, barley, corn, cucumbers, cauliflower, sugarbeets, sunflower)

mg/L - milligrams per litre
 N/A - not available
 < - less than
 ng - no guideline

BOLD indicates samples in exceedance of applied guideline.
 Table should be read in conjunction with accompanying report.

Table A.11
Summary of Current and Historical Surface Water Analytical Results
Total Metals
Bar U Ranch National Historic Site, Alberta
Public Works and Government Services Canada

Reference or Exposure Location	Sample Location	Sample Collection Date	Maxxam Sample ID											
				Total Aluminum (Al)	Total Antimony (Sb)	Total Arsenic (As)	Total Barium (Ba)	Total Beryllium (Be)	Total Boron (B)	Total Cadmium (Cd)	Total Calcium (Ca)	Total Chromium (Cr)	Total Cobalt (Co)	Total Copper (Cu)
Units				mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	ug/L	mg/L	mg/L	mg/L	mg/L
2016 Reportable Detection Limit				0.003	0.0006	0.0002	0.01	0.001	0.02	0.00002	0.3	0.001	0.0003	0.0002
CCME FAL ^(a)				0.1	ng	0.005	ng	ng	1.5	0.0003	ng	ng	ng	0.004
CCME AG ^(b)				5	ng	0.025	ng	0.1	0.5	5.1	1,000	ng	0.05	0.2
Reference	SW15-01 (Upstream)	27-Nov-15	NS8665	0.0084	<0.00060	0.00031	0.14	<0.0010	<0.020	<0.020	76	<0.0010	<0.00030	0.00043
Exposure	SW15-02 (Downstream)	27-Nov-15	NS8666	0.015	<0.00060	0.00021	0.13	<0.0010	<0.020	<0.020	76	<0.0010	<0.00030	0.00043
Reference	SW16-01-01	26-Oct-16	PW6554	0.0068	<0.00060	<0.00020	0.13	<0.0010	<0.020	<0.020	66	<0.0010	<0.00030	<0.00020
Reference	SW16-01-02	26-Oct-16	PW6555	0.014	<0.00060	<0.00020	0.13	<0.0010	<0.020	<0.020	64	0.0057	<0.00030	0.00039
Reference	SW16-01-03	26-Oct-16	PW6556	0.02	<0.00060	<0.00020	0.13	<0.0010	<0.020	<0.020	65	<0.0010	<0.00030	0.00029
Reference	SW16-01-04	26-Oct-16	PW6557	0.0085	<0.00060	0.00023	0.13	<0.0010	<0.020	<0.020	66	<0.0010	<0.00030	<0.00020
Exposure	SW16-02-01	26-Oct-16	PW6558	0.027	<0.00060	<0.00020	0.13	<0.0010	<0.020	<0.020	65	<0.0010	<0.00030	<0.00020
Exposure	SW16-02-02	26-Oct-16	PW6559	0.0078	<0.00060	<0.00020	0.13	<0.0010	<0.020	<0.020	64	0.01	<0.00030	0.00026
Exposure	SW16-02-04	26-Oct-16	PW6560	0.0071	<0.00060	<0.00020	0.13	<0.0010	<0.020	<0.020	65	<0.0010	<0.00030	<0.00020
Exposure	SW16-02-03	26-Oct-16	PW6561	0.01	<0.00060	<0.00020	0.13	<0.0010	<0.020	<0.020	66	<0.0010	<0.00030	0.00021
Reference	SW16-03-01	26-Oct-16	PW6562	0.016	<0.00060	<0.00020	0.13	<0.0010	<0.020	<0.020	65	0.0079	<0.00030	0.00059
Reference	SW16-03-02	26-Oct-16	PW6569	0.0082	<0.00060	<0.00020	0.13	<0.0010	<0.020	<0.020	66	<0.0010	<0.00030	<0.00020
Reference	SW16-03-03	26-Oct-16	PW6570	0.01	<0.00060	0.00025	0.15	<0.0010	<0.020	0.038	70	<0.0010	<0.00030	0.00099
Reference	SW16-04-01	26-Oct-16	PW6571	0.0066	<0.00060	<0.00020	0.13	<0.0010	<0.020	<0.020	66	<0.0010	<0.00030	<0.00020
Reference	SW16-04-02	26-Oct-16	PW6572	0.0085	<0.00060	0.00023	0.15	<0.0010	<0.020	<0.020	69	<0.0010	<0.00030	0.00067
Reference	SW16-05-01	26-Oct-16	PW6573	0.0063	<0.00060	<0.00020	0.13	<0.0010	<0.020	<0.020	65	0.0041	<0.00030	<0.00020
Reference	SW16-05-02	26-Oct-16	PW6574	0.0067	<0.00060	<0.00020	0.13	<0.0010	<0.020	<0.020	63	<0.0010	<0.00030	<0.00020
Exposure	SW16-06-01	26-Oct-16	PW6575	0.008	<0.00060	<0.00020	0.13	<0.0010	<0.020	<0.020	67	<0.0010	<0.00030	<0.00020
Exposure	SW16-06-02	26-Oct-16	PW6576	0.011	<0.00060	<0.00020	0.13	<0.0010	<0.020	<0.020	64	0.001	<0.00030	0.00034
Exposure	SW16-06-03	26-Oct-16	PW6577	0.0076	<0.00060	0.00021	0.12	<0.0010	<0.020	<0.020	62	<0.0010	<0.00030	0.00035
Exposure	SW16-07-01	26-Oct-16	PW6578	0.014	<0.00060	<0.00020	0.13	<0.0010	<0.020	<0.020	66	0.0018	<0.00030	0.00042
Exposure	SW16-07-02	26-Oct-16	PW6584	0.025	<0.00060	<0.00020	0.13	<0.0010	<0.020	<0.020	64	<0.0010	<0.00030	0.00021
Exposure	SW16-08-01	26-Oct-16	PW6585	0.012	<0.00060	<0.00020	0.13	<0.0010	<0.020	<0.020	66	<0.0010	<0.00030	<0.00020
Exposure	SW16-08-02	26-Oct-16	PW6586	0.045	<0.00060	<0.00020	0.13	<0.0010	<0.020	<0.020	64	0.0023	<0.00030	0.00028

Notes:
(a) Canadian Council of Ministers of the Environment (CCME) Canadian Water Quality Guidelines for the Protection of Freshwater Aquatic Life (FAL), current to 2017. A pH value of >6.5 was considered for aluminum, and a minimum hardness value of 220 mg/L was considered for cadmium, copper, lead and nickel.

(b) Canadian Council of Ministers of the Environment (CCME) Canadian Water Quality Guidelines for the Protection of Agricultural (Ag) Water Uses (Irrigation and Livestock Water), current to 2017.

mg/L - milligrams per litre

ug/L - micrograms per litre

< - less than

BOLD indicates samples in exceedance of applied guideline.

Table should be read in conjunction with accompanying report.

Table A.11
Summary of Current and Historical Surface Water Analytical Results
Total Metals
Bar U Ranch National Historic Site, Alberta
Public Works and Government Services Canada

Reference or Exposure Location	Sample Location	Sample Collection Date	Maxxam Sample ID	Parameters										
				Total Iron (Fe)	Total Lead (Pb)	Total Lithium (Li)	Total Magnesium (Mg)	Total Manganese (Mn)	Total Molybdenum (Mo)	Total Nickel (Ni)	Total Phosphorus (P)	Total Potassium (K)	Total Selenium (Se)	Total Silicon (Si)
Units				mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
2016 Reportable Detection Limit				0.06	0.0002	0.02	0.2	0.004	0.0002	0.0005	0.1	0.3	0.0002	0.1
CCME FAL ^(a)				0.3	0.007	ng	ng	ng	0.073	0.15	ng	ng	0.001	ng
CCME AG ^(b)				5	0.1	2.5	ng	0.2	0.5	0.2	ng	ng	0.05	ng
Reference	SW15-01 (Upstream)	27-Nov-15	NS8665	<0.060	<0.00020	<0.020	17	<0.0040	0.00088	0.00069	<0.10	0.54	0.00052	2.4
Exposure	SW15-02 (Downstream)	27-Nov-15	NS8666	<0.060	<0.00020	<0.020	17	<0.0040	0.00081	0.00052	<0.10	0.77	0.00072	2.4
Reference	SW16-01-01	26-Oct-16	PW6554	< 0.0060	< 0.00020	< 0.020	14	< 0.0040	0.00078	0.00062	< 0.10	0.99	0.00036	2.6
Reference	SW16-01-02	26-Oct-16	PW6555	< 0.0060	0.00021	< 0.020	13	< 0.0040	0.00089	0.002	< 0.10	0.92	0.00033	2.5
Reference	SW16-01-03	26-Oct-16	PW6556	< 0.0060	< 0.00020	< 0.020	14	< 0.0040	0.0008	0.00069	< 0.10	0.94	0.00038	2.6
Reference	SW16-01-04	26-Oct-16	PW6557	< 0.0060	< 0.00020	< 0.020	14	< 0.0040	0.00074	< 0.00050	< 0.10	0.96	0.00036	2.6
Exposure	SW16-02-01	26-Oct-16	PW6558	< 0.0060	< 0.00020	< 0.020	13	< 0.0040	0.00068	< 0.00050	< 0.10	0.99	0.00032	2.6
Exposure	SW16-02-02	26-Oct-16	PW6559	< 0.0060	< 0.00020	< 0.020	13	< 0.0040	0.00087	0.0038	< 0.10	0.98	0.00025	2.5
Exposure	SW16-02-04	26-Oct-16	PW6560	< 0.0060	< 0.00020	< 0.020	13	< 0.0040	0.00071	< 0.00050	< 0.10	0.96	0.00025	2.5
Exposure	SW16-02-03	26-Oct-16	PW6561	< 0.0060	< 0.00020	< 0.020	13	< 0.0040	0.00078	0.0006	< 0.10	0.96	0.00036	2.6
Reference	SW16-03-01	26-Oct-16	PW6562	< 0.0060	< 0.00020	< 0.020	13	< 0.0040	0.00091	0.004	< 0.10	0.93	0.00041	2.6
Reference	SW16-03-02	26-Oct-16	PW6569	< 0.0060	< 0.00020	< 0.020	14	< 0.0040	0.00073	0.0006	< 0.10	0.94	0.00031	2.6
Reference	SW16-03-03	26-Oct-16	PW6570	< 0.0060	< 0.00020	< 0.020	15	< 0.0040	0.00095	0.0011	< 0.10	1.1	0.0003	2.8
Reference	SW16-04-01	26-Oct-16	PW6571	< 0.0060	< 0.00020	< 0.020	13	< 0.0040	0.00073	0.00061	< 0.10	0.87	0.00034	2.6
Reference	SW16-04-02	26-Oct-16	PW6572	< 0.0060	< 0.00020	< 0.020	15	< 0.0040	0.00084	0.00063	< 0.10	1.1	0.00039	2.8
Reference	SW16-05-01	26-Oct-16	PW6573	< 0.0060	< 0.00020	< 0.020	13	< 0.0040	0.00079	0.0014	< 0.10	0.9	< 0.00020	2.5
Reference	SW16-05-02	26-Oct-16	PW6574	< 0.0060	< 0.00020	< 0.020	13	< 0.0040	0.00072	0.00053	< 0.10	0.87	0.00037	2.5
Exposure	SW16-06-01	26-Oct-16	PW6575	< 0.0060	< 0.00020	< 0.020	14	< 0.0040	0.00076	< 0.00050	< 0.10	0.99	0.00033	2.6
Exposure	SW16-06-02	26-Oct-16	PW6576	< 0.0060	< 0.00020	< 0.020	13	< 0.0040	0.00071	0.0013	< 0.10	0.94	0.00035	2.5
Exposure	SW16-06-03	26-Oct-16	PW6577	< 0.0060	< 0.00020	< 0.020	13	< 0.0040	0.00071	0.0008	< 0.10	0.95	0.0003	2.4
Exposure	SW16-07-01	26-Oct-16	PW6578	< 0.0060	< 0.00020	< 0.020	13	< 0.0040	0.00079	0.0015	< 0.10	0.98	0.0003	2.6
Exposure	SW16-07-02	26-Oct-16	PW6584	< 0.0060	< 0.00020	< 0.020	13	< 0.0040	0.00077	< 0.00050	< 0.10	0.95	0.00033	2.5
Exposure	SW16-08-01	26-Oct-16	PW6585	< 0.0060	< 0.00020	< 0.020	13	< 0.0040	0.00078	0.00052	< 0.10	0.93	0.00031	2.6
Exposure	SW16-08-02	26-Oct-16	PW6586	< 0.0060	< 0.00020	< 0.020	13	< 0.0040	0.00069	0.00063	< 0.10	0.9	0.00024	2.5

Notes:
(a) Canadian Council of Ministers of the Environment (CCME) Canadian Water Quality Guidelines for the Protection of Freshwater Aquatic Life (FAL), current to 2017. A pH value of >6.5 was considered for aluminum, and a minimum hardness value of 220 mg/L was considered for cadmium, copper, lead and nickel.

(b) Canadian Council of Ministers of the Environment (CCME) Canadian Water Quality Guidelines for the Protection of Agricultural (Ag) Water Uses (Irrigation and Livestock Water), current to 2017.

mg/L - milligrams per litre

ug/L - micrograms per litre

< - less than

BOLD indicates samples in exceedance of applied guideline.

Table should be read in conjunction with accompanying report.

Table A.11
Summary of Current and Historical Surface Water Analytical Results
Total Metals
Bar U Ranch National Historic Site, Alberta
Public Works and Government Services Canada

Reference or Exposure Location	Sample Location	Sample Collection Date	Maxxam Sample ID										
				Total Silver (Ag)	Total Sodium (Na)	Total Strontium (Sr)	Total Sulphur (S)	Total Thallium (Tl)	Total Tin (Sn)	Total Titanium (Ti)	Total Uranium (U)	Total Vanadium (V)	Total Zinc (Zn)
Units				mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
2016 Reportable Detection Limit				0.0001	0.5	0.02	0.2	0.0002	0.001	0.001	0.0001	0.001	0.003
CCME FAL ^(a)				0.00025	ng	ng	ng	0.0008	ng	ng	0.015	ng	0.03
CCME AG ^(b)				ng	ng	ng	ng	ng	ng	ng	0.01	0.1	5
Reference	SW15-01 (Upstream)	27-Nov-15	NS8665	<0.00010	5.5	0.36	11	<0.00020	<0.0010	<0.0010	0.00067	<0.0010	<0.0030
Exposure	SW15-02 (Downstream)	27-Nov-15	NS8666	<0.00010	5.5	0.37	11	<0.00020	<0.0010	<0.0010	0.00066	<0.0010	<0.0030
Reference	SW16-01-01	26-Oct-16	PW6554	<0.00010	5.7	0.32	8.4	<0.00020	<0.0010	<0.0010	0.00041	<0.0010	<0.0030
Reference	SW16-01-02	26-Oct-16	PW6555	<0.00010	5.4	0.31	8	<0.00020	<0.0010	<0.0010	0.00044	<0.0010	<0.0030
Reference	SW16-01-03	26-Oct-16	PW6556	<0.00010	5.6	0.32	8.2	<0.00020	<0.0010	<0.0010	0.00044	<0.0010	<0.0030
Reference	SW16-01-04	26-Oct-16	PW6557	<0.00010	5.7	0.32	8.4	<0.00020	<0.0010	<0.0010	0.0004	<0.0010	<0.0030
Exposure	SW16-02-01	26-Oct-16	PW6558	<0.00010	5.8	0.32	8.3	<0.00020	<0.0010	<0.0010	0.00041	<0.0010	<0.0030
Exposure	SW16-02-02	26-Oct-16	PW6559	<0.00010	5.5	0.31	8.1	<0.00020	<0.0010	<0.0010	0.00039	<0.0010	<0.0030
Exposure	SW16-02-04	26-Oct-16	PW6560	<0.00010	5.5	0.31	8.2	<0.00020	<0.0010	<0.0010	0.00041	<0.0010	<0.0030
Exposure	SW16-02-03	26-Oct-16	PW6561	<0.00010	5.4	0.31	8.3	<0.00020	<0.0010	<0.0010	0.00046	<0.0010	<0.0030
Reference	SW16-03-01	26-Oct-16	PW6562	<0.00010	5.5	0.32	8.2	<0.00020	<0.0010	<0.0010	0.00043	<0.0010	<0.0030
Reference	SW16-03-02	26-Oct-16	PW6569	<0.00010	5.5	0.32	8.3	<0.00020	<0.0010	<0.0010	0.00039	<0.0010	<0.0030
Reference	SW16-03-03	26-Oct-16	PW6570	<0.00010	6.5	0.35	9.2	<0.00020	<0.0010	<0.0010	0.00054	<0.0010	0.0063
Reference	SW16-04-01	26-Oct-16	PW6571	<0.00010	5.4	0.31	7.9	<0.00020	<0.0010	<0.0010	0.0004	<0.0010	<0.0030
Reference	SW16-04-02	26-Oct-16	PW6572	<0.00010	6.5	0.35	9.1	<0.00020	<0.0010	<0.0010	0.0005	<0.0010	<0.0030
Reference	SW16-05-01	26-Oct-16	PW6573	<0.00010	5.4	0.31	8.1	<0.00020	<0.0010	<0.0010	0.00041	<0.0010	<0.0030
Reference	SW16-05-02	26-Oct-16	PW6574	<0.00010	5.3	0.3	8	<0.00020	<0.0010	<0.0010	0.0004	<0.0010	<0.0030
Exposure	SW16-06-01	26-Oct-16	PW6575	<0.00010	5.6	0.32	8.5	<0.00020	<0.0010	<0.0010	0.00042	<0.0010	<0.0030
Exposure	SW16-06-02	26-Oct-16	PW6576	<0.00010	5.3	0.3	8	<0.00020	<0.0010	<0.0010	0.00041	<0.0010	<0.0030
Exposure	SW16-06-03	26-Oct-16	PW6577	<0.00010	5.3	0.3	7.8	<0.00020	<0.0010	<0.0010	0.00041	<0.0010	<0.0030
Exposure	SW16-07-01	26-Oct-16	PW6578	<0.00010	5.5	0.32	8.2	<0.00020	<0.0010	<0.0010	0.00039	<0.0010	<0.0030
Exposure	SW16-07-02	26-Oct-16	PW6584	<0.00010	5.4	0.31	8.1	<0.00020	<0.0010	<0.0010	0.0004	<0.0010	<0.0030
Exposure	SW16-08-01	26-Oct-16	PW6585	<0.00010	5.5	0.32	8.3	<0.00020	<0.0010	<0.0010	0.00041	<0.0010	<0.0030
Exposure	SW16-08-02	26-Oct-16	PW6586	<0.00010	5.3	0.31	8	<0.00020	<0.0010	<0.0010	0.00042	<0.0010	<0.0030

Notes:

(a) Canadian Council of Ministers of the Environment (CCME) Canadian Water Quality Guidelines for the Protection of Freshwater Aquatic Life (FAL), current to 2017. A pH value of >6.5 was considered for aluminum, and a minimum hardness value of 220 mg/L was considered for cadmium, copper, lead and nickel.

(b) Canadian Council of Ministers of the Environment (CCME) Canadian Water Quality Guidelines for the Protection of Agricultural (Ag) Water Uses (Irrigation and Livestock Water), current to 2017.

mg/L - milligrams per litre

ug/L - micrograms per litre

< - less than

BOLD indicates samples in exceedance of applied guideline.

Table should be read in conjunction with accompanying report.

Table A.12
Summary of Current and Historic Surface Water Analytical Results
Polycyclic Aromatic Hydrocarbons
Bar U Ranch National Historic Site, Alberta
Public Works and Government Services Canada

Reference or Exposure Location	Sample Location	Sample Collection Date	Maxxam Sample ID	Parameters													
				Acenaphthene	Acenaphthylene	Acridine	Anthracene	Benzo[a]anthracene	Benzo [b,j] fluoranthene	Benzo[k]fluoranthene	Benzo[g,h,i]perylene	Benzo[c]phenanthrene	Benzo[a]pyrene	Benzo[e]pyrene	Chrysene	Dibenzo[a,h]anthracene	Fluoranthene
Units				mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
2016 Reportable Detection Limit				0.0001	0.0001	0.0002	0.00001	0.0000085	0.0000085	0.0000085	0.0000085	0.00005	0.0000075	0.00005	0.0000085	0.0000075	0.00001
CCME FAL ^(a)				0.0058	ng	0.0044	0.000012	0.000018	ng	ng	ng	ng	0.000015	ng	ng	ng	0.00004
CCME AG ^(b)				ng	ng	ng	ng	ng	ng	ng	ng	ng	ng	ng	ng	ng	ng
Reference	SW15-01 (Upstream)	27-Nov-15	NS8665	<0.00010	<0.00010	<0.00020	<0.000010	<0.0000085	<0.0000085	<0.0000085	<0.0000085	<0.0000050	<0.0000075	<0.0000050	<0.0000085	<0.0000075	<0.000010
Exposure	SW15-02 (Downstream)	27-Nov-15	NS8666	<0.00010	<0.00010	<0.00020	<0.000010	<0.0000085	<0.0000085	<0.0000085	<0.0000085	<0.0000050	<0.0000075	<0.0000050	<0.0000085	<0.0000075	<0.000010
Reference	SW16-01-01	26-Oct-16	PW6554	<0.00010	<0.00010	<0.00020	<0.000010	<0.0000085	<0.0000085	<0.0000085	<0.0000085	<0.0000050	<0.0000075	<0.0000050	<0.0000085	<0.0000075	<0.000010
Reference	SW16-01-02	26-Oct-16	PW6555	<0.00010	<0.00010	<0.00020	<0.000010	<0.0000085	<0.0000085	<0.0000085	<0.0000085	<0.0000050	<0.0000075	<0.0000050	<0.0000085	<0.0000075	<0.000010
Reference	SW16-01-03	26-Oct-16	PW6556	<0.00010	<0.00010	<0.00020	<0.000010	<0.0000085	<0.0000085	<0.0000085	<0.0000085	<0.0000050	<0.0000075	<0.0000050	<0.0000085	<0.0000075	<0.000010
Reference	SW16-01-04	26-Oct-16	PW6557	<0.00010	<0.00010	<0.00020	<0.000010	<0.0000085	<0.0000085	<0.0000085	<0.0000085	<0.0000050	<0.0000075	<0.0000050	<0.0000085	<0.0000075	<0.000010
Exposure	SW16-02-01	26-Oct-16	PW6558	<0.00010	<0.00010	<0.00020	<0.000010	<0.0000085	<0.0000085	<0.0000085	<0.0000085	<0.0000050	<0.0000075	<0.0000050	<0.0000085	<0.0000075	<0.000010
Exposure	SW16-02-02	26-Oct-16	PW6559	<0.00010	<0.00010	<0.00020	<0.000010	<0.0000085	<0.0000085	<0.0000085	<0.0000085	<0.0000050	<0.0000075	<0.0000050	<0.0000085	<0.0000075	<0.000010
Exposure	SW16-02-04	26-Oct-16	PW6560	<0.00010	<0.00010	<0.00020	<0.000010	<0.0000085	<0.0000085	<0.0000085	<0.0000085	<0.0000050	<0.0000075	<0.0000050	<0.0000085	<0.0000075	<0.000010
Exposure	SW16-02-03	26-Oct-16	PW6561	<0.00010	<0.00010	<0.00020	<0.000010	<0.0000085	<0.0000085	<0.0000085	<0.0000085	<0.0000050	<0.0000075	<0.0000050	<0.0000085	<0.0000075	<0.000010
Reference	SW16-03-01	26-Oct-16	PW6562	<0.00010	<0.00010	<0.00020	<0.000010	<0.0000085	<0.0000085	<0.0000085	<0.0000085	<0.0000050	<0.0000075	<0.0000050	<0.0000085	<0.0000075	<0.000010
Reference	SW16-03-02	26-Oct-16	PW6569	<0.00010	<0.00010	<0.00020	<0.000010	<0.0000085	<0.0000085	<0.0000085	<0.0000085	<0.0000050	<0.0000075	<0.0000050	<0.0000085	<0.0000075	<0.000010
Reference	SW16-03-03	26-Oct-16	PW6570	<0.00010	<0.00010	<0.00020	<0.000010	<0.0000085	<0.0000085	<0.0000085	<0.0000085	<0.0000050	<0.0000075	<0.0000050	<0.0000085	<0.0000075	<0.000010
Reference	SW16-04-01	26-Oct-16	PW6571	<0.00010	<0.00010	<0.00020	<0.000010	<0.0000085	<0.0000085	<0.0000085	<0.0000085	<0.0000050	<0.0000075	<0.0000050	<0.0000085	<0.0000075	<0.000010
Reference	SW16-04-02	26-Oct-16	PW6572	<0.00010	<0.00010	<0.00020	<0.000010	<0.0000085	<0.0000085	<0.0000085	<0.0000085	<0.0000050	<0.0000075	<0.0000050	<0.0000085	<0.0000075	<0.000010
Reference	SW16-05-01	26-Oct-16	PW6573	<0.00010	<0.00010	<0.00020	<0.000010	<0.0000085	<0.0000085	<0.0000085	<0.0000085	<0.0000050	<0.0000075	<0.0000050	<0.0000085	<0.0000075	<0.000010
Reference	SW16-05-02	26-Oct-16	PW6574	<0.00010	<0.00010	<0.00020	<0.000010	<0.0000085	<0.0000085	<0.0000085	<0.0000085	<0.0000050	<0.0000075	<0.0000050	<0.0000085	<0.0000075	<0.000010
Exposure	SW16-06-01	26-Oct-16	PW6575	<0.00010	<0.00010	<0.00020	<0.000010	<0.0000085	<0.0000085	<0.0000085	<0.0000085	<0.0000050	<0.0000075	<0.0000050	<0.0000085	<0.0000075	<0.000010
Exposure	SW16-06-02	26-Oct-16	PW6576	<0.00010	<0.00010	<0.00020	<0.000010	<0.0000085	<0.0000085	<0.0000085	<0.0000085	<0.0000050	<0.0000075	<0.0000050	<0.0000085	<0.0000075	<0.000010
Exposure	SW16-06-03	26-Oct-16	PW6577	<0.00010	<0.00010	<0.00020	<0.000010	<0.0000085	<0.0000085	<0.0000085	<0.0000085	<0.0000050	<0.0000075	<0.0000050	<0.0000085	<0.0000075	<0.000010
Exposure	SW16-07-01	26-Oct-16	PW6578	<0.00010	<0.00010	<0.00020	<0.000010	<0.0000085	<0.0000085	<0.0000085	<0.0000085	<0.0000050	<0.0000075	<0.0000050	<0.0000085	<0.0000075	<0.000010
Exposure	SW16-07-02	26-Oct-16	PW6584	<0.00010	<0.00010	<0.00020	<0.000010	<0.0000085	<0.0000085	<0.0000085	<0.0000085	<0.0000050	<0.0000075	<0.0000050	<0.0000085	<0.0000075	<0.000010
Exposure	SW16-08-01	26-Oct-16	PW6585	<0.00010	<0.00010	<0.00020	<0.000010	<0.0000085	<0.0000085	<0.0000085	<0.0000085	<0.0000050	<0.0000075	<0.0000050	<0.0000085	<0.0000075	<0.000010
Exposure	SW16-08-02	26-Oct-16	PW6586	<0.00010	<0.00010	<0.00020	<0.000010	<0.0000085	<0.0000085	<0.0000085	<0.0000085	<0.0000050	<0.0000075	<0.0000050	<0.0000085	<0.0000075	<0.000010

Notes:
 (a) Canadian Council of Ministers of the Environment (CCME) Canadian Water Quality Guidelines for the Protection of Freshwater Aquatic Life (FAL), current to 2017.
 (b) Canadian Council of Ministers of the Environment (CCME) Canadian Water Quality Guidelines for the Protection of Agricultural (Ag) Water Uses (Irrigation and Livestock Water), current to 2017.

mg/L - milligrams per litre
 N/A - not available
 < - less than

BOLD indicates samples in exceedance of applied guideline.
 Table should be read in conjunction with accompanying report.

Table A.12
Summary of Current and Historic Surface Water Analytical Results
Polycyclic Aromatic Hydrocarbons
Bar U Ranch National Historic Site, Alberta
Public Works and Government Services Canada

Reference or Exposure Location	Sample Location	Sample Collection Date	Maxxam Sample ID									
				Fluorene	Indeno[1,2,3-cd]pyrene	2-Methylnaphthalene	Naphthalene	Perylene	Phenanthrene	Pyrene	Quinoline	B(a)P Equivalency
Units				mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
2016 Reportable Detection Limit				0.00005	0.0000085	0.0001	0.0001	0.00005	0.00005	0.00002	0.0002	0.00001
CCME FAL ^(a)				0.003	ng	ng	0.0011	ng	0.0004	0.000025	0.0034	ng
CCME AG ^(b)				ng	ng	ng	ng	ng	ng	ng	ng	ng
Reference	SW15-01 (Upstream)	27-Nov-15	NS8665	<0.000050	<0.0000085	<0.00010	<0.00010	<0.000050	<0.000050	<0.000020	<0.00020	<0.000010
Exposure	SW15-02 (Downstream)	27-Nov-15	NS8666	<0.000050	<0.0000085	<0.00010	<0.00010	<0.000050	<0.000050	<0.000020	<0.00020	<0.000010
Reference	SW16-01-01	26-Oct-16	PW6554	<0.000050	<0.0000085	<0.00010	<0.00010	<0.000050	<0.000050	<0.000020	<0.00020	<0.000010
Reference	SW16-01-02	26-Oct-16	PW6555	<0.000050	<0.0000085	<0.00010	<0.00010	<0.000050	<0.000050	<0.000020	<0.00020	<0.000010
Reference	SW16-01-03	26-Oct-16	PW6556	<0.000050	<0.0000085	<0.00010	<0.00010	<0.000050	<0.000050	<0.000020	<0.00020	<0.000010
Reference	SW16-01-04	26-Oct-16	PW6557	<0.000050	<0.0000085	<0.00010	<0.00010	<0.000050	<0.000050	<0.000020	<0.00020	<0.000010
Exposure	SW16-02-01	26-Oct-16	PW6558	<0.000050	<0.0000085	<0.00010	<0.00010	<0.000050	<0.000050	<0.000020	<0.00020	<0.000010
Exposure	SW16-02-02	26-Oct-16	PW6559	<0.000050	<0.0000085	<0.00010	<0.00010	<0.000050	<0.000050	<0.000020	<0.00020	<0.000010
Exposure	SW16-02-04	26-Oct-16	PW6560	<0.000050	<0.0000085	<0.00010	<0.00010	<0.000050	<0.000050	<0.000020	<0.00020	<0.000010
Exposure	SW16-02-03	26-Oct-16	PW6561	<0.000050	<0.0000085	<0.00010	<0.00010	<0.000050	<0.000050	<0.000020	<0.00020	<0.000010
Reference	SW16-03-01	26-Oct-16	PW6562	<0.000050	<0.0000085	<0.00010	<0.00010	<0.000050	<0.000050	<0.000020	<0.00020	<0.000010
Reference	SW16-03-02	26-Oct-16	PW6569	<0.000050	<0.0000085	<0.00010	<0.00010	<0.000050	<0.000050	<0.000020	<0.00020	<0.000010
Reference	SW16-03-03	26-Oct-16	PW6570	<0.000050	<0.0000085	<0.00010	<0.00010	<0.000050	<0.000050	<0.000020	<0.00020	<0.000010
Reference	SW16-04-01	26-Oct-16	PW6571	<0.000050	<0.0000085	<0.00010	<0.00010	<0.000050	<0.000050	<0.000020	<0.00020	<0.000010
Reference	SW16-04-02	26-Oct-16	PW6572	<0.000050	<0.0000085	<0.00010	<0.00010	<0.000050	<0.000050	<0.000020	<0.00020	<0.000010
Reference	SW16-05-01	26-Oct-16	PW6573	<0.000050	<0.0000085	<0.00010	<0.00010	<0.000050	<0.000050	<0.000020	<0.00020	<0.000010
Reference	SW16-05-02	26-Oct-16	PW6574	<0.000050	<0.0000085	<0.00010	<0.00010	<0.000050	<0.000050	<0.000020	<0.00020	<0.000010
Exposure	SW16-06-01	26-Oct-16	PW6575	<0.000050	<0.0000085	<0.00010	<0.00010	<0.000050	<0.000050	<0.000020	<0.00020	<0.000010
Exposure	SW16-06-02	26-Oct-16	PW6576	<0.000050	<0.0000085	<0.00010	<0.00010	<0.000050	<0.000050	<0.000020	<0.00020	<0.000010
Exposure	SW16-06-03	26-Oct-16	PW6577	<0.000050	<0.0000085	<0.00010	<0.00010	<0.000050	<0.000050	<0.000020	<0.00020	<0.000010
Exposure	SW16-07-01	26-Oct-16	PW6578	<0.000050	<0.0000085	<0.00010	<0.00010	<0.000050	<0.000050	<0.000020	<0.00020	<0.000010
Exposure	SW16-07-02	26-Oct-16	PW6584	<0.000050	<0.0000085	<0.00010	<0.00010	<0.000050	<0.000050	<0.000020	<0.00020	<0.000010
Exposure	SW16-08-01	26-Oct-16	PW6585	<0.000050	<0.0000085	<0.00010	<0.00010	<0.000050	<0.000050	<0.000020	<0.00020	<0.000010
Exposure	SW16-08-02	26-Oct-16	PW6586	<0.000050	<0.0000085	<0.00010	<0.00010	<0.000050	<0.000050	<0.000020	<0.00020	<0.000010

Notes:
(a) Canadian Council of Ministers of the Environment (CCME) Canadian Water Quality Guidelines for the Protection of Freshwater Aquatic Life (FAL), current to 2017.
(b) Canadian Council of Ministers of the Environment (CCME) Canadian Water Quality Guidelines for the Protection of Agricultural (Ag) Water Uses (Irrigation and Livestock Water), current to 2017.

mg/L - milligrams per litre
N/A - not available
< - less than

BOLD indicates samples in exceedance of applied guideline.
Table should be read in conjunction with accompanying report.

Table A.13
Summary of Sediment Analytical Results - Polycyclic Aromatic Hydrocarbons
Bar U Ranch National Historic Site, Alberta
Public Works and Government Services Canada

Reference or Exposure Location			CCME Guidelines ISQGs ^(a)	CCME Guidelines PELs ^(b)	Reference	Reference	Reference	Reference	Reference	Reference	Reference	Reference	Reference	Reference	
Sample Identification					SD16-01-01 (c)	SD16-01-02	SD16-01-03 (c)	SD16-01-04 (c)	SD16-03-01 (c)	SD16-03-02	SD16-03-03	SD16-04-01	SD16-04-02 (c)	SD16-05-01	SD16-05-02
Sample Depth (m bgs)					0.0-0.1	0.0-0.1	0.0-0.1	0.0-0.1	0.0-0.1	0.0-0.1	0.0-0.1	0.0-0.1	0.0-0.1	0.0-0.1	
Sample Collection Date					26-Oct-16	26-Oct-16	26-Oct-16	26-Oct-16	26-Oct-16	26-Oct-16	26-Oct-16	26-Oct-16	26-Oct-16	26-Oct-16	
Parameter	Units	2016 RDL													
Acenaphthene	mg/kg	0.005	0.00671	0.0889	< 0.010	< 0.0050	< 0.012	< 0.010	< 0.010	< 0.0050	< 0.0050	< 0.0050	< 0.017	< 0.0050	< 0.0050
Acenaphthylene	mg/kg	0.005	0.00587	0.128	< 0.010	< 0.0050	< 0.012	< 0.010	< 0.010	< 0.0050	< 0.0050	< 0.0050	< 0.017	< 0.0050	< 0.0050
Acridine	mg/kg	0.01	ng	ng	< 0.020	< 0.010	< 0.023	< 0.020	< 0.020	< 0.010	< 0.010	< 0.010	< 0.033	< 0.010	< 0.010
Anthracene	mg/kg	0.004	0.0469	0.245	< 0.0080	< 0.0040	< 0.0092	< 0.0080	< 0.0080	< 0.0040	< 0.0040	< 0.0040	< 0.013	< 0.0040	< 0.0040
Benzo(a)anthracene	mg/kg	0.005	0.0317	0.358	< 0.010	< 0.0050	< 0.012	< 0.010	< 0.010	< 0.0050	< 0.0050	< 0.0050	< 0.017	< 0.0050	< 0.0050
Benzo(b&j)fluoranthene	mg/kg	0.005	ng	ng	0.013	0.013	0.015	0.012	0.016	0.011	0.012	0.011	< 0.017	0.0079	0.01
Benzo(k)fluoranthene	mg/kg	0.005	ng	ng	< 0.010	< 0.0050	< 0.012	< 0.010	< 0.010	< 0.0050	< 0.0050	< 0.0050	< 0.017	< 0.0050	< 0.0050
Benzo(g,h,i)perylene	mg/kg	0.005	ng	ng	< 0.010	< 0.0050	< 0.012	< 0.010	0.013	0.0086	< 0.0050	0.013	< 0.017	0.01	0.012
Benzo(c)phenanthrene	mg/kg	0.005	ng	ng	< 0.010	< 0.0050	< 0.012	< 0.010	< 0.010	< 0.0050	< 0.0050	< 0.0050	< 0.017	< 0.0050	< 0.0050
Benzo(a)pyrene	mg/kg	0.005	0.0319	0.782	< 0.010	< 0.0050	< 0.012	< 0.010	< 0.010	< 0.0050	< 0.0050	< 0.0050	< 0.017	< 0.0050	< 0.0050
Benzo(e)pyrene	mg/kg	0.005	ng	ng	0.017	0.016	0.021	0.016	0.023	0.016	0.015	0.019	0.019	0.014	0.017
Chrysene	mg/kg	0.005	0.0571	0.862	< 0.010	0.012	< 0.012	< 0.010	0.015	< 0.0050	0.0094	0.01	< 0.017	< 0.0050	0.0087
Dibenz(a,h)anthracene	mg/kg	0.005	0.00622	0.135	< 0.010	< 0.0050	< 0.012	< 0.010	< 0.010	< 0.0050	< 0.0050	< 0.0050	< 0.017	< 0.0050	< 0.0050
Fluoranthene	mg/kg	0.005	0.111	2.355	< 0.010	< 0.0050	< 0.012	< 0.010	< 0.010	< 0.0050	< 0.0050	< 0.0050	< 0.017	< 0.0050	< 0.0050
Fluorene	mg/kg	0.005	0.0212	0.144	< 0.010	< 0.0050	< 0.012	< 0.010	< 0.010	< 0.0050	< 0.0050	< 0.0050	< 0.017	< 0.0050	< 0.0050
Indeno(1,2,3-cd)pyrene	mg/kg	0.005	ng	ng	< 0.010	< 0.0050	< 0.012	< 0.010	< 0.010	< 0.0050	< 0.0050	< 0.0050	< 0.017	< 0.0050	< 0.0050
2-Methylnaphthalene	mg/kg	0.005	0.0202	0.201	0.039	0.037	0.048	0.039	0.036	0.033	0.033	0.024	0.06	0.026	0.022
Naphthalene	mg/kg	0.005	0.0346	0.391	0.02	0.024	0.025	0.02	0.019	0.019	0.017	0.013	0.029	0.011	0.0091
Phenanthrene	mg/kg	0.005	0.0419	0.515	0.038	0.041	0.048	0.036	0.047	0.032	0.029	0.035	0.049	0.025	0.034
Perylene	mg/kg	0.005	ng	ng	0.011	0.0094	0.017	0.013	< 0.010	0.011	0.0096	< 0.0050	< 0.017	< 0.0050	< 0.0050
Pyrene	mg/kg	0.005	0.0530	0.875	< 0.010	< 0.0050	< 0.012	< 0.010	0.011	< 0.0050	< 0.0050	0.0099	< 0.017	< 0.0050	0.0089
Quinoline	mg/kg	0.01	ng	ng	< 0.020	< 0.010	< 0.023	< 0.020	< 0.020	< 0.010	< 0.010	< 0.010	< 0.033	< 0.010	< 0.010

Notes:
 (a) Canadian Council of Ministers of the Environment (CCME) Canadian Sediment Quality Guidelines for the Protection of Aquatic Life in Freshwater, Interim Sediment Quality Guidelines (ISQGs), current to 2017
 (b) Canadian Council of Ministers of the Environment (CCME) Canadian Sediment Quality Guidelines for the Protection of Aquatic Life in Freshwater, Probable Effect Levels (PELs), current to 2017.
 (c) Detection limits raised due to high moisture content, sample contains >50% moisture.
 mg/kg - milligrams per kilogram
 ppm - parts per million
 m bgs - metres below ground surface
 RDL - reported detection limit
 N/A - not available
 ng - no guideline

BOLD indicates samples in exceedance of applied PELs. ISQGs shown for comparison purposes only.

Table should be read in conjunction with accompanying report.

Table A.13
Summary of Sediment Analytical Results - Polycyclic Aromatic Hydrocarbons
Bar U Ranch National Historic Site, Alberta
Public Works and Government Services Canada

Reference or Exposure Location			CCME Guidelines ISQGs ^(a)	CCME Guidelines PELs ^(b)	Exposure	Exposure	Exposure	Exposure	Exposure	Exposure	Exposure	Exposure	Exposure	Exposure	Exposure
Sample Identification					SD16-02-01	SD16-02-02	SD16-02-03	SD16-02-04	SD16-06-01 (c)	SD16-06-02 (c)	SD16-06-03	SD16-07-01 (c)	SD16-07-02 (c)	SD16-08-01	SD16-08-02
Sample Depth (m bgs)					0.0-0.1	0.0-0.1	0.0-0.1	0.0-0.1	0.0-0.1	0.0-0.1	0.0-0.1	0.0-0.1	0.0-0.1	0.0-0.1	0.0-0.1
Sample Collection Date					26-Oct-16	26-Oct-16	26-Oct-16	26-Oct-16	26-Oct-16	26-Oct-16	26-Oct-16	26-Oct-16	26-Oct-16	26-Oct-16	26-Oct-16
Parameter	Units	2016 RDL													
Acenaphthene	mg/kg	0.005	0.00671	0.0889	< 0.0050	< 0.0050	< 0.0050	< 0.0050	< 0.0095	< 0.010	< 0.0050	< 0.014	< 0.020	< 0.0050	< 0.0050
Acenaphthylene	mg/kg	0.005	0.00587	0.128	< 0.0050	< 0.0050	< 0.0050	< 0.0050	< 0.0095	< 0.010	< 0.0050	< 0.014	< 0.020	< 0.0050	< 0.0050
Acridine	mg/kg	0.01	ng	ng	< 0.010	< 0.010	< 0.010	< 0.010	< 0.019	< 0.020	< 0.010	< 0.028	< 0.040	< 0.010	< 0.010
Anthracene	mg/kg	0.004	0.0469	0.245	< 0.0040	< 0.0040	< 0.0040	< 0.0040	< 0.0076	< 0.0080	< 0.0040	< 0.011	< 0.016	< 0.0040	< 0.0040
Benzo(a)anthracene	mg/kg	0.005	0.0317	0.358	< 0.0050	< 0.0050	< 0.0050	< 0.0050	< 0.0095	< 0.010	< 0.0050	< 0.014	< 0.020	< 0.0050	< 0.0050
Benzo(b&j)fluoranthene	mg/kg	0.005	ng	ng	0.011	0.011	0.012	0.0076	0.014	0.012	0.012	< 0.014	< 0.020	0.012	0.015
Benzo(k)fluoranthene	mg/kg	0.005	ng	ng	< 0.0050	< 0.0050	< 0.0050	< 0.0050	< 0.0095	< 0.010	< 0.0050	< 0.014	< 0.020	< 0.0050	< 0.0050
Benzo(g,h,i)perylene	mg/kg	0.005	ng	ng	< 0.0050	0.0082	0.0091	< 0.0050	< 0.0095	< 0.010	< 0.0050	< 0.014	< 0.020	0.014	0.019
Benzo(c)phenanthrene	mg/kg	0.005	ng	ng	< 0.0050	< 0.0050	< 0.0050	< 0.0050	< 0.0095	< 0.010	< 0.0050	< 0.014	< 0.020	< 0.0050	< 0.0050
Benzo(a)pyrene	mg/kg	0.005	0.0319	0.782	< 0.0050	< 0.0050	< 0.0050	< 0.0050	< 0.0095	< 0.010	< 0.0050	< 0.014	< 0.020	< 0.0050	< 0.0050
Benzo(e)pyrene	mg/kg	0.005	ng	ng	0.014	0.014	0.015	0.0097	0.018	0.017	0.015	< 0.014	< 0.020	0.02	0.026
Chrysene	mg/kg	0.005	0.0571	0.862	0.0088	0.0091	0.0094	< 0.0050	0.013	< 0.010	0.01	< 0.014	< 0.020	0.011	0.014
Dibenz(a,h)anthracene	mg/kg	0.005	0.00622	0.135	< 0.0050	< 0.0050	< 0.0050	< 0.0050	< 0.0095	< 0.010	< 0.0050	< 0.014	< 0.020	< 0.0050	< 0.0050
Fluoranthene	mg/kg	0.005	0.111	2.355	< 0.0050	< 0.0050	< 0.0050	< 0.0050	< 0.0095	< 0.010	< 0.0050	< 0.014	< 0.020	< 0.0050	0.0078
Fluorene	mg/kg	0.005	0.0212	0.144	< 0.0050	< 0.0050	< 0.0050	< 0.0050	< 0.0095	< 0.010	< 0.0050	< 0.014	< 0.020	0.0075	0.007
Indeno(1,2,3-cd)pyrene	mg/kg	0.005	ng	ng	< 0.0050	< 0.0050	< 0.0050	< 0.0050	< 0.0095	< 0.010	< 0.0050	< 0.014	< 0.020	< 0.0050	< 0.0050
2-Methylnaphthalene	mg/kg	0.005	0.0202	0.201	0.032	0.024	0.028	0.022	0.061	0.053	0.035	0.046	0.062	0.023	0.026
Naphthalene	mg/kg	0.005	0.0346	0.391	0.018	0.012	0.018	0.01	0.029	0.03	0.02	0.022	0.029	0.0093	0.012
Phenanthrene	mg/kg	0.005	0.0419	0.515	0.03	0.029	0.033	0.024	0.051	0.042	0.037	0.04	0.05	0.051	0.048
Perylene	mg/kg	0.005	ng	ng	0.0096	0.0079	< 0.0050	< 0.0050	0.012	0.012	< 0.0050	< 0.014	< 0.020	< 0.0050	0.009
Pyrene	mg/kg	0.005	0.0530	0.875	0.0085	0.0084	0.0094	< 0.0050	< 0.0095	< 0.010	< 0.0050	< 0.014	< 0.020	0.013	0.017
Quinoline	mg/kg	0.01	ng	ng	< 0.010	< 0.010	< 0.010	< 0.010	< 0.019	< 0.020	< 0.010	< 0.028	< 0.040	< 0.010	< 0.010

Notes:
(a) Canadian Council of Ministers of the Environment (CCME) Canadian Sediment Quality Guidelines for the Protection of Aquatic Life in Freshwater, Interim Sediment Quality Guidelines (ISQGs), current to 2017
(b) Canadian Council of Ministers of the Environment (CCME) Canadian Sediment Quality Guidelines for the Protection of Aquatic Life in Freshwater, Probable Effect Levels (PELs), current to 2017.
(c) Detection limits raised due to high moisture content, sample contains >50% moisture.
mg/kg - milligrams per kilogram
ppm - parts per million
m bgs - metres below ground surface
RDL - reported detection limit
N/A - not available
ng - no guideline

BOLD indicates samples in exceedance of applied PELs. ISQGs shown for comparison purposes only.

Table should be read in conjunction with accompanying report.

Table A.14
Summary of Sediment Analytical Results - Metals
Bar U Ranch National Historic Site, Alberta
Public Works and Government Services Canada

Reference or Exposure Location			CCME Guidelines ISQGs ^(a)	CCME Guidelines PELs ^(b)	Reference										
Sample Identification					SD16-01-01	SD16-01-02	SD16-01-03	SD16-01-04	SD16-03-01	SD16-03-02	SD16-03-03	SD16-04-01	SD16-04-02	SD16-05-01	SD16-05-02
Sample Depth (m bgs)					0.0-0.1	0.0-0.1	0.0-0.1	0.0-0.1	0.0-0.1	0.0-0.1	0.0-0.1	0.0-0.1	0.0-0.1	0.0-0.1	0.0-0.1
Sample Collection Date					26-Oct-16										
Parameter	Units	2016 RDL													
Total Antimony (Sb)	mg/kg	0.5	ng	ng	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50
Total Arsenic (As)	mg/kg	1	5.9	17	5.1	4.9	4.9	5	6.5	4.7	4.7	6.7	4.2	7.9	6.3
Total Barium (Ba)	mg/kg	1	ng	ng	230	230	230	240	200	220	240	210	250	180	170
Total Beryllium (Be)	mg/kg	0.4	ng	ng	0.5	0.48	0.57	0.51	0.5	0.47	0.49	0.47	0.45	0.56	0.53
Soluble (Hot water) Boron (B)	mg/kg	0.1	ng	ng	0.19	0.26	0.2	0.19	0.21	0.49	0.39	0.17	0.2	0.11	0.15
Total Cadmium (Cd)	mg/kg	0.05	0.6	3.5	0.35	0.37	0.41	0.49	0.34	0.38	0.36	0.32	0.55	0.4	0.35
Hex. Chromium (Cr 6+)	mg/kg	0.08	ng	ng	< 0.080	< 0.080	< 0.080	< 0.080	< 0.080	< 0.080	< 0.080	< 0.080	< 0.080	< 0.080	< 0.080
Total Chromium (Cr)	mg/kg	1	37.3	90	21	19	13	14	18	17	14	20	24	16	14
Total Cobalt (Co)	mg/kg	0.5	ng	ng	6.3	6.3	6.4	6.5	7.1	6.3	6.4	6.6	6.1	8.1	6.6
Total Copper (Cu)	mg/kg	1	35.7	197	13	13	15	14	18	19	27	18	30	23	19
Total Lead (Pb)	mg/kg	0.5	35	91.3	7.5	7.8	8.1	8	8.5	7.9	8	7.9	8	9.6	8
Total Mercury (Hg)	mg/kg	0.05	0.17	0.486	< 0.050	< 0.050	< 0.050	< 0.050	< 0.050	< 0.050	< 0.050	< 0.050	< 0.050	< 0.050	< 0.050
Total Molybdenum (Mo)	mg/kg	0.4	ng	ng	0.81	0.68	0.61	0.63	0.8	0.7	0.59	0.89	0.66	1	0.73
Total Nickel (Ni)	mg/kg	1	ng	ng	23	22	20	20	24	22	20	24	24	27	21
Total Selenium (Se)	mg/kg	0.5	ng	ng	0.56	0.6	0.7	0.62	0.51	0.61	0.64	< 0.50	0.82	< 0.50	< 0.50
Total Silver (Ag)	mg/kg	0.2	ng	ng	< 0.20	< 0.20	< 0.20	< 0.20	< 0.20	< 0.20	< 0.20	< 0.20	< 0.20	< 0.20	< 0.20
Total Thallium (Tl)	mg/kg	0.1	ng	ng	< 0.10	< 0.10	0.11	< 0.10	0.1	< 0.10	0.1	0.1	0.1	0.11	< 0.10
Total Tin (Sn)	mg/kg	1	ng	ng	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0
Total Uranium (U)	mg/kg	0.2	ng	ng	0.48	0.45	0.46	0.5	0.52	0.54	0.47	0.54	0.47	0.64	0.54
Total Vanadium (V)	mg/kg	1	ng	ng	23	22	23	24	27	24	26	27	21	32	26
Total Zinc (Zn)	mg/kg	10	123	315	66	67	70	69	75	70	74	69	79	88	73

Notes:

(a) Canadian Council of Ministers of the Environment (CCME) Canadian Sediment Quality Guidelines for the Protection of Aquatic Life in Freshwater, Interim Sediment Quality Guidelines (ISQGs), current to 2017.

(b) Canadian Council of Ministers of the Environment (CCME) Canadian Sediment Quality Guidelines for the Protection of Aquatic Life in Freshwater, Probably Effect Levels (PELs), current to 2017.

mg/kg - milligrams per kilogram

ppm - parts per million

m bgs - metres below ground surface

RDL - reported detection limit

ng - no guideline

BOLD indicates samples in exceedance of applied PELs. ISQGs shown for comparison

Table should be read in conjunction with accompanying report.

Table A.14
Summary of Sediment Analytical Results - Metals
Bar U Ranch National Historic Site, Alberta
Public Works and Government Services Canada

Reference or Exposure Location			CCME Guidelines ISQGs ^(a)	CCME Guidelines PELs ^(b)	Exposure										
Sample Identification					SD16-02-01	SD16-02-02	SD16-02-03	SD16-02-04	SD16-06-01	SD16-06-02	SD16-06-03	SD16-07-01	SD16-07-02	SD16-08-01	SD16-08-02
Sample Depth (m bgs)					0.0-0.1	0.0-0.1	0.0-0.1	0.0-0.1	0.0-0.1	0.0-0.1	0.0-0.1	0.0-0.1	0.0-0.1	0.0-0.1	0.0-0.1
Sample Collection Date					26-Oct-16										
Parameter	Units	2016 RDL													
Total Antimony (Sb)	mg/kg	0.5	ng	ng	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50
Total Arsenic (As)	mg/kg	1	5.9	17	6.2	7.1	7.4	5.3	4.2	4.3	3.7	3.6	3	7.5	7
Total Barium (Ba)	mg/kg	1	ng	ng	200	210	210	230	260	200	230	230	220	180	200
Total Beryllium (Be)	mg/kg	0.4	ng	ng	0.48	0.57	0.6	0.55	0.49	< 0.40	0.54	0.53	0.46	0.51	0.54
Soluble (Hot water) Boron (B)	mg/kg	0.1	ng	ng	0.41	0.35	0.22	0.67	0.12	0.16	0.34	2.2	4.1	< 0.10	0.14
Total Cadmium (Cd)	mg/kg	0.05	0.6	3.5	0.33	0.4	0.4	0.5	0.49	0.4	0.39	0.57	0.56	0.31	0.33
Hex. Chromium (Cr 6+)	mg/kg	0.08	ng	ng	< 0.080	< 0.080	< 0.080	< 0.080	< 0.080	< 0.080	< 0.080	< 0.080	< 0.080	< 0.080	< 0.080
Total Chromium (Cr)	mg/kg	1	37.3	90	17	30	28	21	15	13	14	21	11	31	14
Total Cobalt (Co)	mg/kg	0.5	ng	ng	6.8	7.4	7.1	7.1	6	5.9	6.3	5.3	5.7	7.1	7
Total Copper (Cu)	mg/kg	1	35.7	197	14	20	19	22	29	13	19	21	16	18	17
Total Lead (Pb)	mg/kg	0.5	35	91.3	8.3	9	9.1	9.1	8	7.5	8.2	7	7.7	8.9	8.9
Total Mercury (Hg)	mg/kg	0.05	0.17	0.486	< 0.050	< 0.050	< 0.050	< 0.050	< 0.050	< 0.050	< 0.050	0.07	< 0.050	< 0.050	< 0.050
Total Molybdenum (Mo)	mg/kg	0.4	ng	ng	0.73	1.6	1.3	0.98	0.65	0.49	0.57	1	0.58	1.1	0.84
Total Nickel (Ni)	mg/kg	1	ng	ng	23	30	29	25	20	19	21	22	19	29	21
Total Selenium (Se)	mg/kg	0.5	ng	ng	< 0.50	0.7	0.63	0.62	0.81	0.56	0.75	1.4	1.2	< 0.50	< 0.50
Total Silver (Ag)	mg/kg	0.2	ng	ng	< 0.20	< 0.20	< 0.20	< 0.20	< 0.20	< 0.20	< 0.20	< 0.20	< 0.20	< 0.20	< 0.20
Total Thallium (Tl)	mg/kg	0.1	ng	ng	< 0.10	0.11	< 0.10	0.14	0.11	< 0.10	0.12	0.15	0.12	0.1	0.1
Total Tin (Sn)	mg/kg	1	ng	ng	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0
Total Uranium (U)	mg/kg	0.2	ng	ng	0.52	0.73	0.63	0.7	0.51	0.41	0.51	0.58	0.64	0.55	0.52
Total Vanadium (V)	mg/kg	1	ng	ng	25	29	31	28	21	18	27	18	20	29	28
Total Zinc (Zn)	mg/kg	10	123	315	70	76	73	85	75	64	71	71	71	74	75

Notes:

(a) Canadian Council of Ministers of the Environment (CCME) Canadian Sediment Quality Guidelines for the Protection of Aquatic Life in Freshwater, Interim Sediment Quality Guidelines (ISQGs), current to 2017.

(b) Canadian Council of Ministers of the Environment (CCME) Canadian Sediment Quality Guidelines for the Protection of Aquatic Life in Freshwater, Probably Effect Levels (PELs), current to 2017.

mg/kg - milligrams per kilogram

ppm - parts per million

m bgs - metres below ground surface

RDL - reported detection limit

ng - no guideline

BOLD indicates samples in exceedance of applied PELs. ISQGs shown for comparison

Table should be read in conjunction with accompanying report.

Table A.15
Summary of Sediment Analytical Results - Detailed Salinity Parameters
Bar U Ranch National Historic Site, Alberta
Public Works and Government Services Canada

Reference or Exposure Location			CCME Guidelines ISQGs ^(a)	CCME Guidelines PELs ^(b)	Reference							
Sample Identification					SD16-01-01	SD16-01-02	SD16-01-03	SD16-01-04	SD16-03-01	SD16-03-02	SD16-03-03	SD16-04-01
Sample Depth (m bgs)					0.0-0.1	0.0-0.1	0.0-0.1	0.0-0.1	0.0-0.1	0.0-0.1	0.0-0.1	0.0-0.1
Sample Collection Date					26-Oct-16							
Parameter	Units	2016 RDL										
Calculated Calcium (Ca)	mg/kg	0.74	ng	ng	57	82	110	71	58	160	77	41
Calculated Magnesium (Mg)	mg/kg	0.5	ng	ng	10	14	19	12	9.4	25	13	6.6
Calculated Sodium (Na)	mg/kg	1.2	ng	ng	8.8	8.9	11	9.1	8.3	13	9.2	6.5
Calculated Potassium (K)	mg/kg	0.64	ng	ng	3.8	6	6.8	4.2	3.3	9.4	4.2	1.7
Calculated Chloride (Cl)	mg/kg	2.5	ng	ng	4.2	9.4	10	7.1	6.9	72	8	9.7
Calculated Sulphate (SO4)	mg/kg	2.5	ng	ng	38	45	56	45	33	340	48	86
Soluble Chloride (Cl)	mg/L	5	ng	ng	6.7	15	14	11	14	110	13	28
Soluble Conductivity	dS/m	0.02	ng	ng	0.54	0.69	0.79	0.6	0.64	1.2	0.71	0.65
Soluble (CaCl2) pH	pH	N/A	ng	ng	7.3	7.29	7.14	7.2	7.13	7	7.13	7.47
Sodium Adsorption Ratio	N/A	0.1	ng	ng	0.35	0.3	0.29	0.32	0.38	0.3	0.33	0.42
Soluble Calcium (Ca)	mg/L	1.5	ng	ng	90	130	140	110	120	240	130	120
Soluble Magnesium (Mg)	mg/L	1	ng	ng	16	22	25	18	20	36	22	19
Soluble Nitrate (N)	mg/L	0.2	ng	ng	14	14	15	14	17	19	15	19
Soluble Sodium (Na)	mg/L	2.5	ng	ng	6.1	9.4	9.1	6.3	6.8	14	7	5
Soluble Potassium (K)	mg/L	1.3	ng	ng	63	64	75	66	48	68	60	34
Soluble Sulphate (SO4)	mg/L	5	ng	ng	61	71	75	68	69	500	80	250
Theoretical Gypsum Requirement	tonnes/ha	0.2	ng	ng	< 0.20	< 0.20	< 0.20	< 0.20	< 0.20	< 0.20	< 0.20	< 0.20

(a) Canadian Council of Ministers of the Environment (CCME) Canadian Sediment Quality Guidelines for the Protection of Aquatic Life in Freshwater, Interim Sediment Quality Guidelines (ISQGs), current to 2017

(b) Canadian Council of Ministers of the Environment (CCME) Canadian Sediment Quality Guidelines for the Protection of Aquatic Life in Freshwater, Probably Effect Levels (PELs), current to 2017.

mg/kg - milligrams per kilogram

mg/L - milligram per litre

dS/m - decisiemens per metre

tonnes/ha - tonnes per hectare

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RDL - reported detection limit

ng - no guideline

N/A - not available

BOLD

indicates samples in exceedance of applied PELs. ISQGs shown for comparison purposes only.

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Table A.15
Summary of Sediment Analytical Results - Detailed Salinity Parameters
Bar U Ranch National Historic Site, Alberta
Public Works and Government Services Canada

Reference or Exposure Location			CCME Guidelines ISQGs ^(a)	CCME Guidelines PELs ^(b)	Reference			Exposure				
Sample Identification					SD16-04-02	SD16-05-01	SD16-05-02	SD16-02-01	SD16-02-02	SD16-02-03	SD16-02-04	SD16-06-01
Sample Depth (m bgs)					0.0-0.1	0.0-0.1	0.0-0.1	0.0-0.1	0.0-0.1	0.0-0.1	0.0-0.1	0.0-0.1
Sample Collection Date					26-Oct-16							
Parameter	Units	2016 RDL										
Calculated Calcium (Ca)	mg/kg	0.74	ng	ng	180	41	62	99	69	58	130	150
Calculated Magnesium (Mg)	mg/kg	0.5	ng	ng	31	7.4	10	15	11	9.2	19	25
Calculated Sodium (Na)	mg/kg	1.2	ng	ng	21	5	7.1	7.4	7.3	6.2	12	14
Calculated Potassium (K)	mg/kg	0.64	ng	ng	9.1	2.3	3.5	4.8	3.1	2.6	6.6	8.5
Calculated Chloride (Cl)	mg/kg	2.5	ng	ng	15	5.1	9.9	60	15	< 1.8	95	8.3
Calculated Sulphate (SO4)	mg/kg	2.5	ng	ng	150	25	66	240	91	77	320	72
Soluble Chloride (Cl)	mg/L	5	ng	ng	17	15	25	140	39	< 5.0	150	9.8
Soluble Conductivity	dS/m	0.02	ng	ng	1.1	0.69	0.83	1.2	0.97	0.87	1.1	0.96
Soluble (CaCl2) pH	pH	N/A	ng	ng	7.08	7.17	7.33	7.13	7.06	7.06	6.87	7.1
Sodium Adsorption Ratio	N/A	0.1	ng	ng	0.4	0.32	0.35	0.28	0.34	0.33	0.31	0.3
Soluble Calcium (Ca)	mg/L	1.5	ng	ng	200	120	160	230	170	160	200	170
Soluble Magnesium (Mg)	mg/L	1	ng	ng	35	21	26	35	28	25	30	30
Soluble Nitrate (N)	mg/L	0.2	ng	ng	23	14	18	17	18	17	18	16
Soluble Sodium (Na)	mg/L	2.5	ng	ng	10	6.6	8.8	11	7.8	7.1	10	10
Soluble Potassium (K)	mg/L	1.3	ng	ng	88	35	40	44	40	36	64	85
Soluble Sulphate (SO4)	mg/L	5	ng	ng	170	70	170	560	230	210	510	85
Theoretical Gypsum Requirement	tonnes/ha	0.2	ng	ng	< 0.20	< 0.20	< 0.20	< 0.20	< 0.20	< 0.20	< 0.20	< 0.20

(a) Canadian Council of Ministers of the Environment (CCME) Canadian Sediment Quality Guidelines for the Protection of Aquatic Life in Freshwater, Interim Sediment Quality Guidelines (ISQGs), current to 2017

(b) Canadian Council of Ministers of the Environment (CCME) Canadian Sediment Quality Guidelines for the Protection of Aquatic Life in Freshwater, Probably Effect Levels (PELs), current to 2017.

mg/kg - milligrams per kilogram

mg/L - milligram per litre

dS/m - decisiemens per metre

tonnes/ha - tonnes per hectare

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RDL - reported detection limit

ng - no guideline

N/A - not available

BOLD

indicates samples in exceedance of applied PELs. ISQGs shown for comparison purposes only.

Table should be read in conjunction with accompanying report.

Table A.15
Summary of Sediment Analytical Results - Detailed Salinity Parameters
Bar U Ranch National Historic Site, Alberta
Public Works and Government Services Canada

Reference or Exposure Location			CCME Guidelines ISQGs ^(a)	CCME Guidelines PELs ^(b)	Exposure					
Sample Identification					SD16-06-02	SD16-06-03	SD16-07-01	SD16-07-02	SD16-08-01	SD16-08-02
Sample Depth (m bgs)					0.0-0.1	0.0-0.1	0.0-0.1	0.0-0.1	0.0-0.1	0.0-0.1
Sample Collection Date					26-Oct-16	26-Oct-16	26-Oct-16	26-Oct-16	26-Oct-16	26-Oct-16
Parameter	Units	2016 RDL								
Calculated Calcium (Ca)	mg/kg	0.74	ng	ng	140	120	270	380	29	37
Calculated Magnesium (Mg)	mg/kg	0.5	ng	ng	21	19	48	64	4.6	6.1
Calculated Sodium (Na)	mg/kg	1.2	ng	ng	15	11	26	27	6.6	6.2
Calculated Potassium (K)	mg/kg	0.64	ng	ng	9.6	5.4	19	15	1.6	2
Calculated Chloride (Cl)	mg/kg	2.5	ng	ng	14	28	18	130	7.1	13
Calculated Sulphate (SO4)	mg/kg	2.5	ng	ng	71	210	99	880	33	69
Soluble Chloride (Cl)	mg/L	5	ng	ng	17	43	14	100	22	36
Soluble Conductivity	dS/m	0.02	ng	ng	0.86	0.96	1.1	1.5	0.55	0.62
Soluble (CaCl2) pH	pH	N/A	ng	ng	7.18	7.22	7.01	6.89	7.71	7.45
Sodium Adsorption Ratio	N/A	0.1	ng	ng	0.35	0.31	0.35	0.31	0.52	0.41
Soluble Calcium (Ca)	mg/L	1.5	ng	ng	170	180	210	310	89	100
Soluble Magnesium (Mg)	mg/L	1	ng	ng	26	29	38	53	14	16
Soluble Nitrate (N)	mg/L	0.2	ng	ng	18	17	21	22	20	17
Soluble Sodium (Na)	mg/L	2.5	ng	ng	12	8.3	15	13	4.7	5.4
Soluble Potassium (K)	mg/L	1.3	ng	ng	81	66	120	120	33	37
Soluble Sulphate (SO4)	mg/L	5	ng	ng	88	320	79	730	100	190
Theoretical Gypsum Requirement	tonnes/ha	0.2	ng	ng	< 0.20	< 0.20	< 0.20	< 0.20	< 0.20	< 0.20

(a) Canadian Council of Ministers of the Environment (CCME) Canadian Sediment Quality Guidelines for the Protection of Aquatic Life in Freshwater, Interim Sediment Quality Guidelines (ISQGs), current to 2017

(b) Canadian Council of Ministers of the Environment (CCME) Canadian Sediment Quality Guidelines for the Protection of Aquatic Life in Freshwater, Probably Effect Levels (PELs), current to 2017.

mg/kg - milligrams per kilogram

mg/L - milligram per litre

dS/m - decisiemens per metre

tonnes/ha - tonnes per hectare

ppm - parts per million

RDL - reported detection limit

ng - no guideline

N/A - not available

BOLD

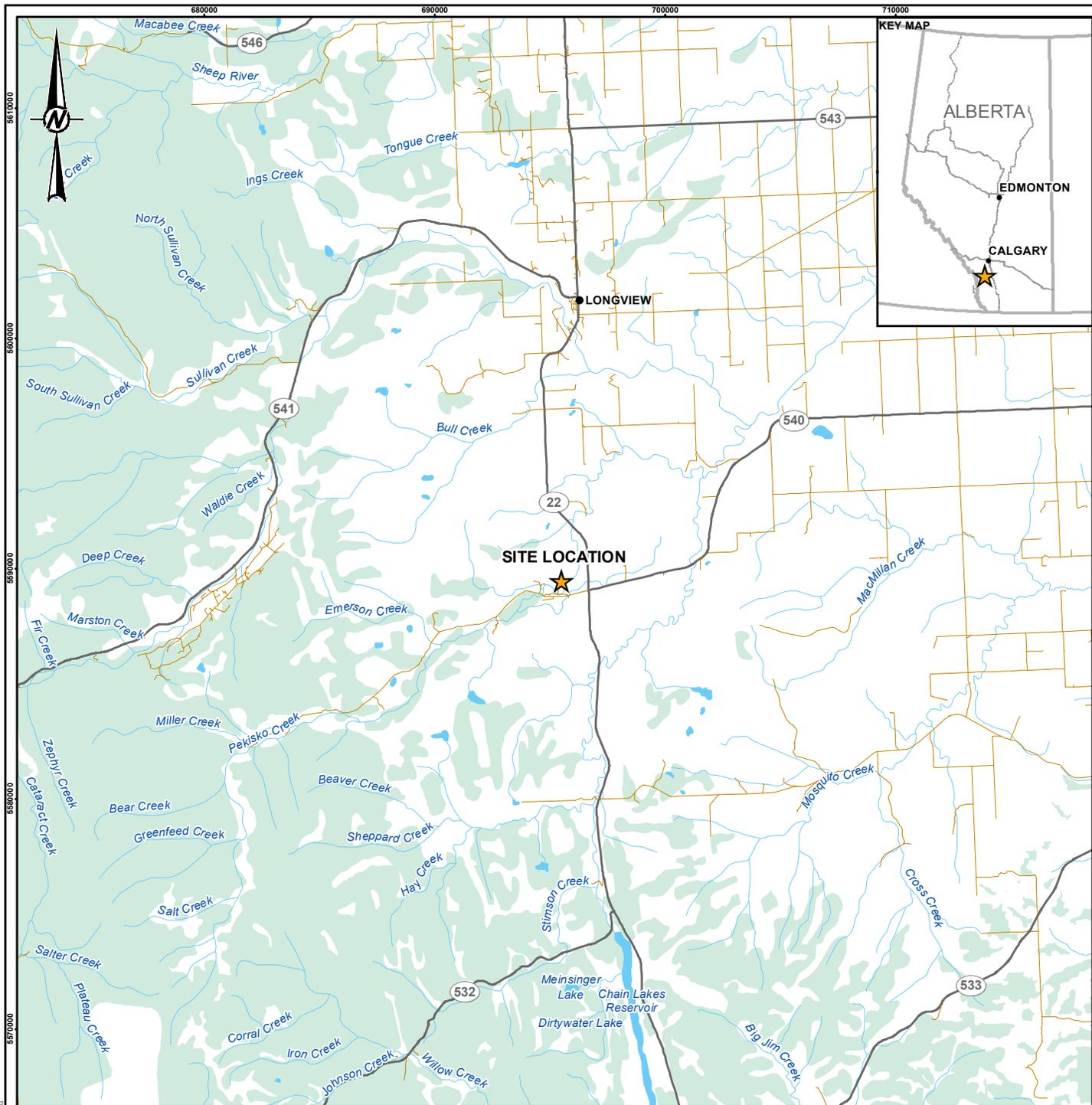
indicates samples in exceedance of applied PELs. ISQGs shown for comparison purposes only.

Table should be read in conjunction with accompanying report.



APPENDIX B

Figures



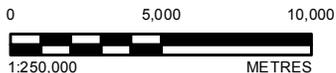
LEGEND

- SITE LOCATION
- POPULATED PLACE
- HIGHWAY
- LOCAL ROAD
- WATERCOURSE
- WATERBODY
- WOODED AREA

CLIENT
PWGSC ENVIRONMENTAL SERVICES

PROJECT
DETAILED QUANTITATIVE HUMAN HEALTH AND ECOLOGICAL RISK ASSESSMENT, BAR U WASTE MIDDENS, WATERTON NATIONAL PARK, LONGVIEW, ALBERTA

TITLE
SITE LOCATION



CONSULTANT



YYYY-MM-DD 2018-02-16

DESIGNED JS

PREPARED LMS

REVIEWED JG

APPROVED JG

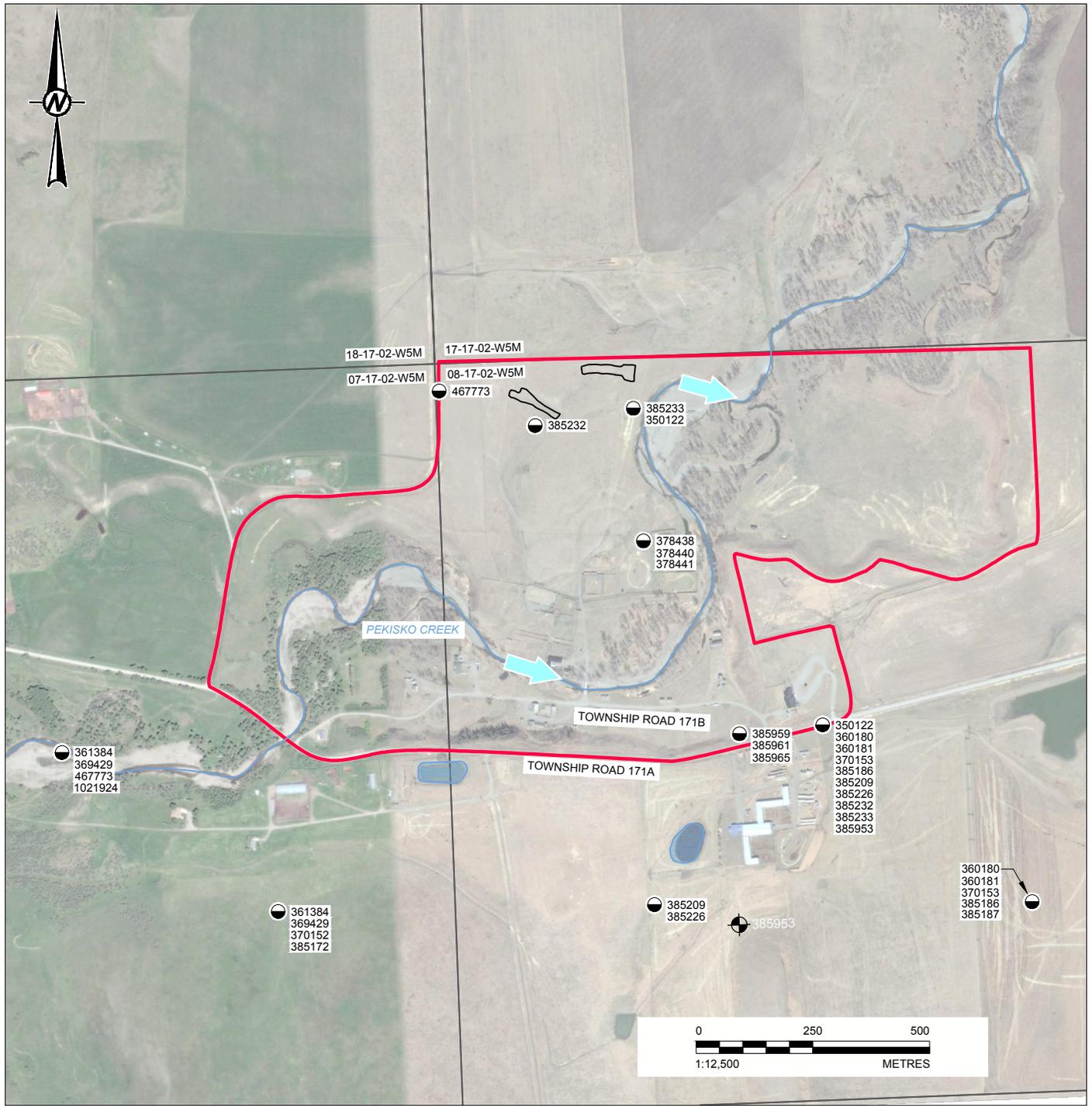
REFERENCE(S)

1. NATIONAL TOPOGRAPHIC DATA BASE (NTDB) DATA OBTAINED FROM GEOGRATIS, © DEPARTMENT OF NATURAL RESOURCES CANADA. ALL RIGHTS RESERVED.
 2. ROADS OBTAINED FROM GEOGRATIS, © DEPARTMENT OF NATURAL RESOURCES CANADA. ALL RIGHTS RESERVED.
- PROJECTION: UTM ZONE 11 DATUM: NAD 83

PROJECT NO.
1663924

REV.
0

FIGURE
1



LEGEND

- SITE BOUNDARY
- WASTE MIDDENS BOUNDARY (APPROXIMATE)
- WATER BODY
- WATER COURSE
- ➔ FLOW DIRECTION
- PRIVATE WATER WELL

REFERENCE

- IMAGE OBTAINED FROM GOOGLE EARTH PRO, USED UNDER LICENSE. IMAGERY DATE: APRIL 10, 2016. GOOGLE EARTH IMAGE IS NOT TO SCALE. NAD83 UTM ZONE 11.
- ORIGINAL DRAWING OBTAINED FROM MERIDIAN ENVIRONMENTAL INC.; JOB NO. 11005
- MIDDENS BOUNDARY PROVIDED BY FOCUS SURVEYS LIMITED PARTNERSHIP, FILE 020300149-Dec5-08.dwg

CLIENT
PWGSC ENVIRONMENTAL SERVICES

PROJECT
DETAILED QUANTITATIVE HUMAN HEALTH AND ECOLOGICAL RISK ASSESSMENT, BAR U WASTE MIDDENS, WATERTON NATIONAL PARK, LONGVIEW, ALBERTA

TITLE
SITE PLAN AND SURROUNDING AREA

CONSULTANT	YYYY-MM-DD	2018-02-16
	PREPARED	MKH
	DESIGN	TR
	REVIEW	JG
	APPROVED	JG



PROJECT No.
1663924

Rev.
0

FIGURE
2



- LEGEND**
- MONITORING WELL LOCATION
 - REFERENCE MONITORING WELL LOCATION
 - BOREHOLE LOCATION
 - MIDDENS APPROXIMATE EXTENTS

- REFERENCE**
- IMAGE OBTAINED FROM GOOGLE EARTH PRO, USED UNDER LICENSE. IMAGERY DATE: APRIL 4, 2016. GOOGLE EARTH IMAGE IS NOT TO SCALE. NAD83 UTM ZONE 11
 - LINENWORK PROVIDED BY FOCUS SURVEYS LIMITED PARTNERSHIP, FILE 020300149-Dec5-08.dwg
 - BOUNDARY OF AREA SURVEYED ON DECEMBER 3, 2008.



CLIENT
PWGSC ENVIRONMENTAL SERVICES

PROJECT
DETAILED QUANTITATIVE HUMAN HEALTH AND ECOLOGICAL RISK ASSESSMENT, BAR U WASTE MIDDENS, WATERTON NATIONAL PARK, LONGVIEW, ALBERTA

TITLE
SITE PLAN

CONSULTANT	YYYY-MM-DD	2018-02-16
	PREPARED	MKH
	DESIGN	TR
	REVIEW	JG
	APPROVED	JG

Path: \\golder\gdp\gdp\saat\con\p\2016\1663924_PWGSC_2016\Env\Monitor_BarU\Figure\DOH\HEBA | File Name: 1663924 - Midden Site Plan.dwg

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM ANS B 28 mm



- LEGEND**
-  MONITORING WELL LOCATION
 -  REFERENCE MONITORING WELL LOCATION
 -  BOREHOLE LOCATION
 -  MIDDENS APPROXIMATE EXTENTS
 -  WASTE OBSERVED
 -  NO CLAY CAP OR <0.5m THICKNESS
 -  ESTIMATED CLAY CAP THICKNESS

- REFERENCE**
- IMAGE OBTAINED FROM GOOGLE EARTH PRO, USED UNDER LICENSE. IMAGERY DATE: APRIL 4, 2016. GOOGLE EARTH IMAGE IS NOT TO SCALE. NAD83 UTM ZONE 11
 - LINWORK PROVIDED BY FOCUS SURVEYS LIMITED PARTNERSHIP, FILE 020300149-Dec5-08.dwg
 - BOUNDARY OF AREA SURVEYED ON DECEMBER 3, 2008.



CLIENT
PWGSC ENVIRONMENTAL SERVICES

PROJECT
DETAILED QUANTITATIVE HUMAN HEALTH AND ECOLOGICAL RISK ASSESSMENT, BAR U WASTE MIDDENS, WATERTON NATIONAL PARK, LONGVIEW, ALBERTA

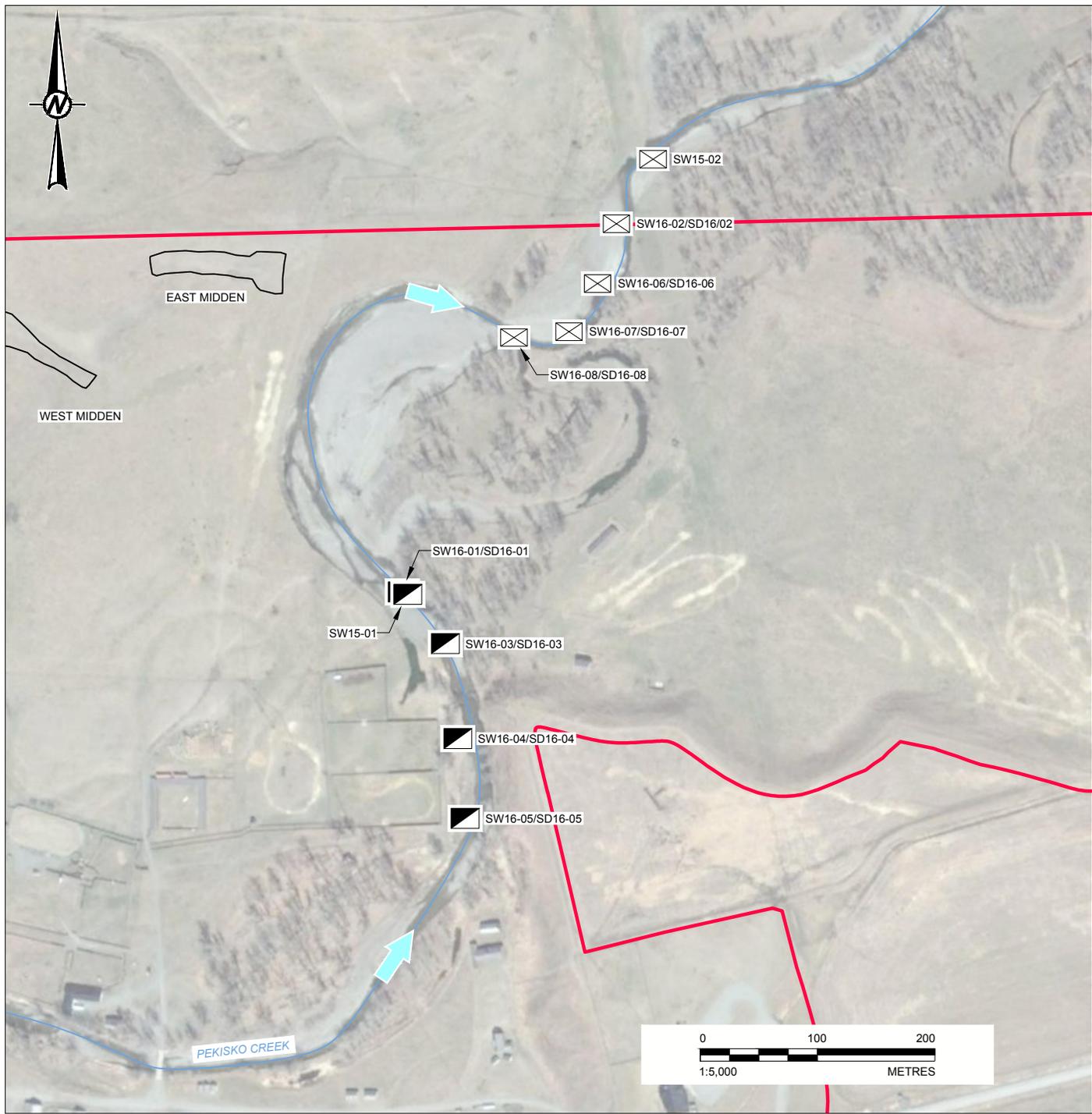
TITLE
MIDDENS CLAY CAP THICKNESS

CONSULTANT	YYYY-MM-DD	2018-02-16
	PREPARED	MKH
	DESIGN	TR
	REVIEW	JG
	APPROVED	JG

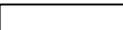
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IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM A3/B

Path: \\golder\gis\assess\env\gis\2016\1663924_PWGSC_2016\Env\Monitor_BarU\Figures\DO\HERA_1 | File Name: 1663924 - SW Sampling Locations.dwg



LEGEND

-  SITE BOUNDARY
-  WASTE MIDDENS BOUNDARY (APPROXIMATE)
-  WATER COURSE
-  FLOW DIRECTION
-  SURFACE WATER LOCATION/SEDIMENT SAMPLE
-  REFERENCE SURFACE WATER LOCATION/SEDIMENT SAMPLE

REFERENCE

- IMAGE OBTAINED FROM GOOGLE EARTH PRO, USED UNDER LICENSE. IMAGERY DATE: APRIL 10, 2016. GOOGLE EARTH IMAGE IS NOT TO SCALE. NAD83 UTM ZONE 11.
- ORIGINAL DRAWING OBTAINED FROM MERIDIAN ENVIRONMENTAL INC, JOB NO. 11005
- MIDDENS BOUNDARY PROVIDED BY FOCUS SURVEYS LIMITED PARTNERSHIP, FILE 020300149-Dec5-08.dwg

CLIENT
PWGSC ENVIRONMENTAL SERVICES

PROJECT
DETAILED QUANTITATIVE HUMAN HEALTH AND ECOLOGICAL RISK ASSESSMENT, BAR U WASTE MIDDENS, WATERTON NATIONAL PARK, LONGVIEW, ALBERTA

TITLE
SURFACE WATER AND SEDIMENT SAMPLE LOCATIONS

CONSULTANT	YYYY-MM-DD	2018-02-16
	PREPARED	MKH
	DESIGN	TR
	REVIEW	JG
	APPROVED	JG



PROJECT No. 1663924 Rev. 0 FIGURE 5

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM ANSIA 26 mm



LEGEND

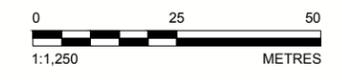
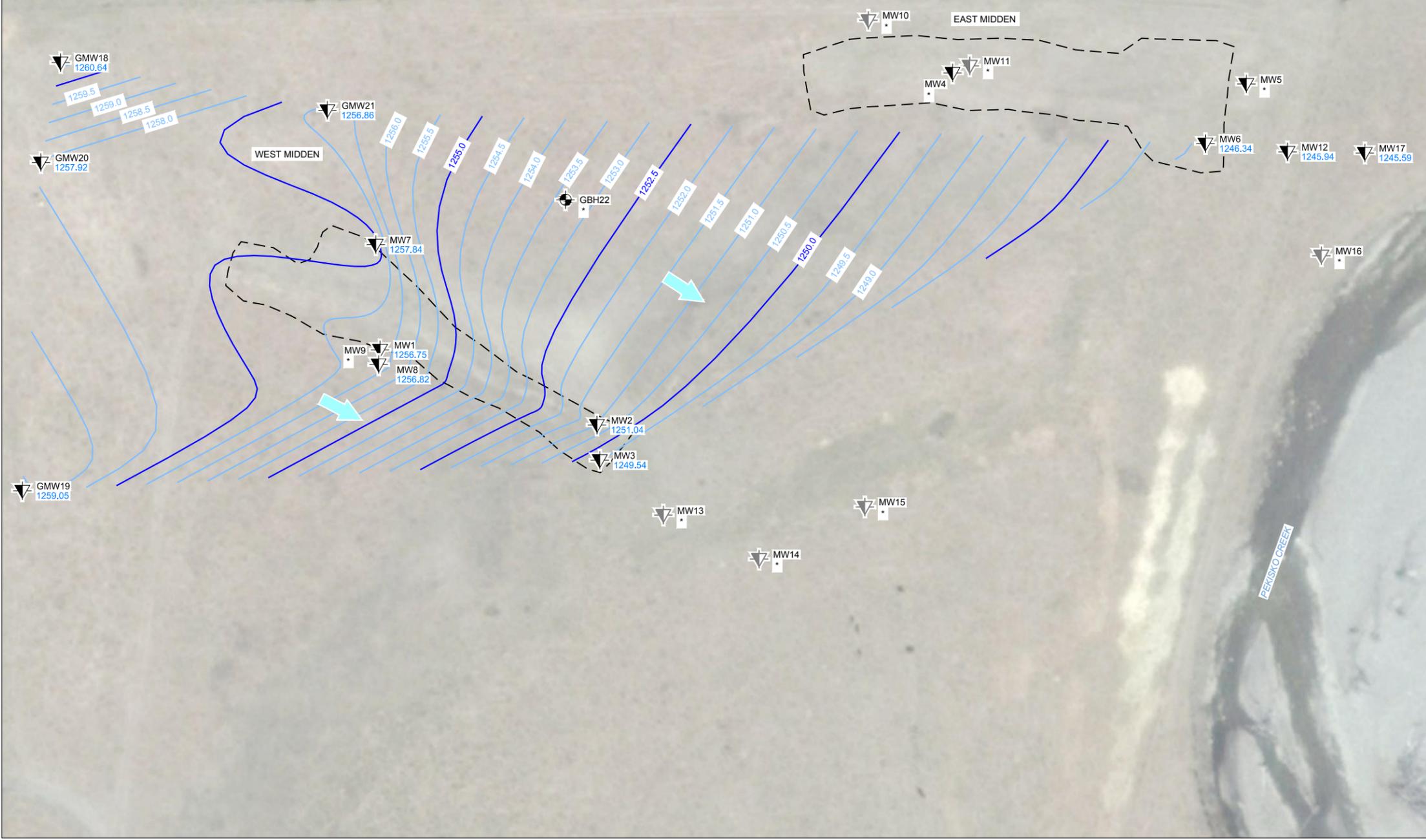
- MONITORING WELL LOCATION
- DESTROYED/MISSING MONITORING WELL LOCATION
- BOREHOLE LOCATION
- GROUNDWATER ELEVATION OF THIS MONITORING WELL WAS NOT USED TO DETERMINE GROUNDWATER FLOW AND CONTOURS
- MIDDENS APPROXIMATE EXTENTS
- FLOW DIRECTION

REFERENCE

- IMAGE OBTAINED FROM GOOGLE EARTH PRO, USED UNDER LICENSE. IMAGERY DATE: APRIL 4, 2016. GOOGLE EARTH IMAGE IS NOT TO SCALE. NAD83 UTM ZONE 11
- LINWORK PROVIDED BY FOCUS SURVEYS LIMITED PARTNERSHIP, FILE 020300149-Dec5-08.dwg
- BOUNDARY OF AREA SURVEYED ON DECEMBER 3, 2008.

NOTES:

1. GROUNDWATER ELEVATION CONTOURS WERE GENERATED BASED ON THE 2016 PCA SURVEY, WHICH DID NOT INCLUDE THE TOP OF CASING ELEVATIONS. THEREFORE, INACCURACIES EXIST IN THE GROUNDWATER ELEVATION DATA SET.



CLIENT
PWGSC ENVIRONMENTAL SERVICES

PROJECT
DETAILED QUANTITATIVE HUMAN HEALTH AND ECOLOGICAL RISK ASSESSMENT, BAR U WASTE MIDDENS, WATERTON NATIONAL PARK, LONGVIEW, ALBERTA

TITLE
GROUNDWATER FLOW DIRECTION

CONSULTANT	YYYY-MM-DD	2018-02-15
	PREPARED	JMC
	DESIGN	ER
	REVIEW	JG
	APPROVED	JG

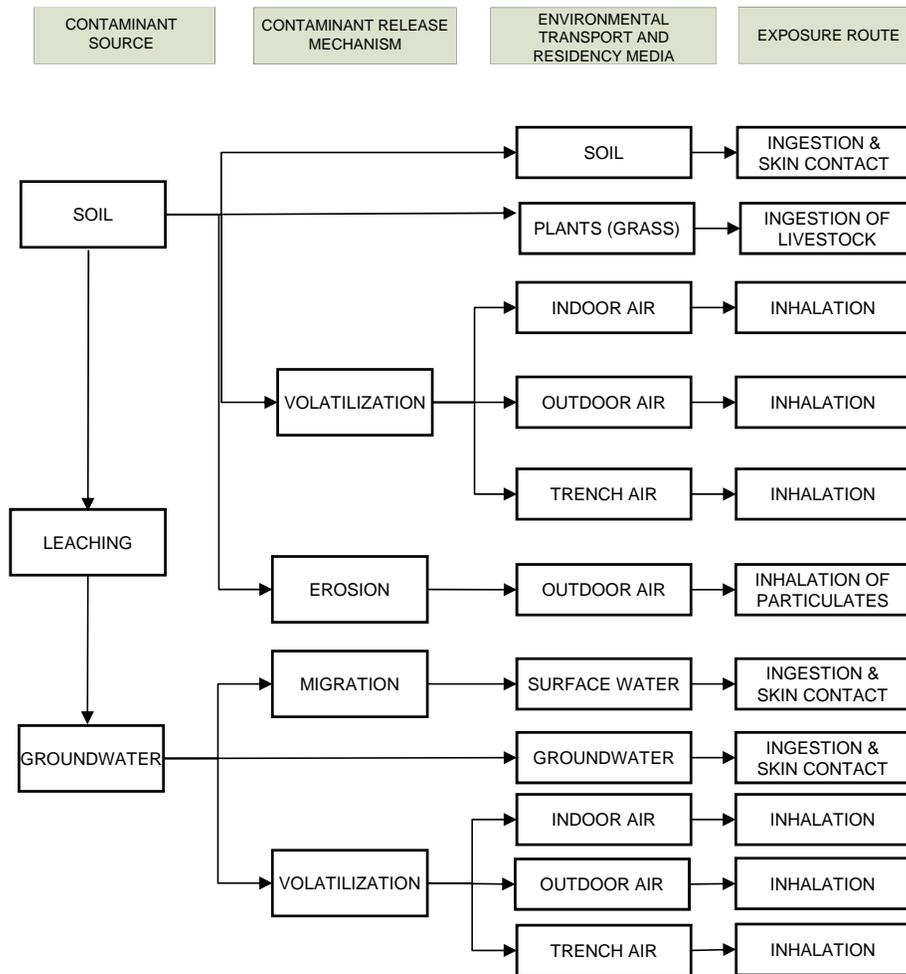


Path: \\golder\gdp\gdp\saas\at\con\p\2016\1663924_PWGSC_2016\Env\Monitor_BarU\Figure\DC\HHEBA | File Name: 1663924 - 2016 GW Flow Direction.dwg

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM A4S B 28 mm

Conceptual Site Model – Human Health

FIGURE 7



ON - SITE RECEPTORS		OFF-SITE RECEPTORS
Ranch Owners/ Employees, and Site Visitors	Construction/ Subsurface Worker	Off-Site Residents
<input checked="" type="checkbox"/> **	<input checked="" type="checkbox"/> **	<input checked="" type="checkbox"/>
<input checked="" type="checkbox"/> **	NA	NA
NA	NA	NA
<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>
NA	<input checked="" type="checkbox"/>	NA
<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>
<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
NA	<input type="checkbox"/>	<input type="checkbox"/>
NA	NA	NA
<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
NA	<input type="checkbox"/>	NA

Legend

- ** Soil-related pathways associated with direct contact exposure are complete and considered in the HHRA, however, not evaluated in the HHRA
- Exposure pathway is complete and retained in the HHRA
- Exposure pathway is complete and not retained in the HHRA
- Exposure pathway is incomplete as no COCs retained for this pathway
- NA Exposure pathway not applicable

Date: July 2018

Project Number: 1663924

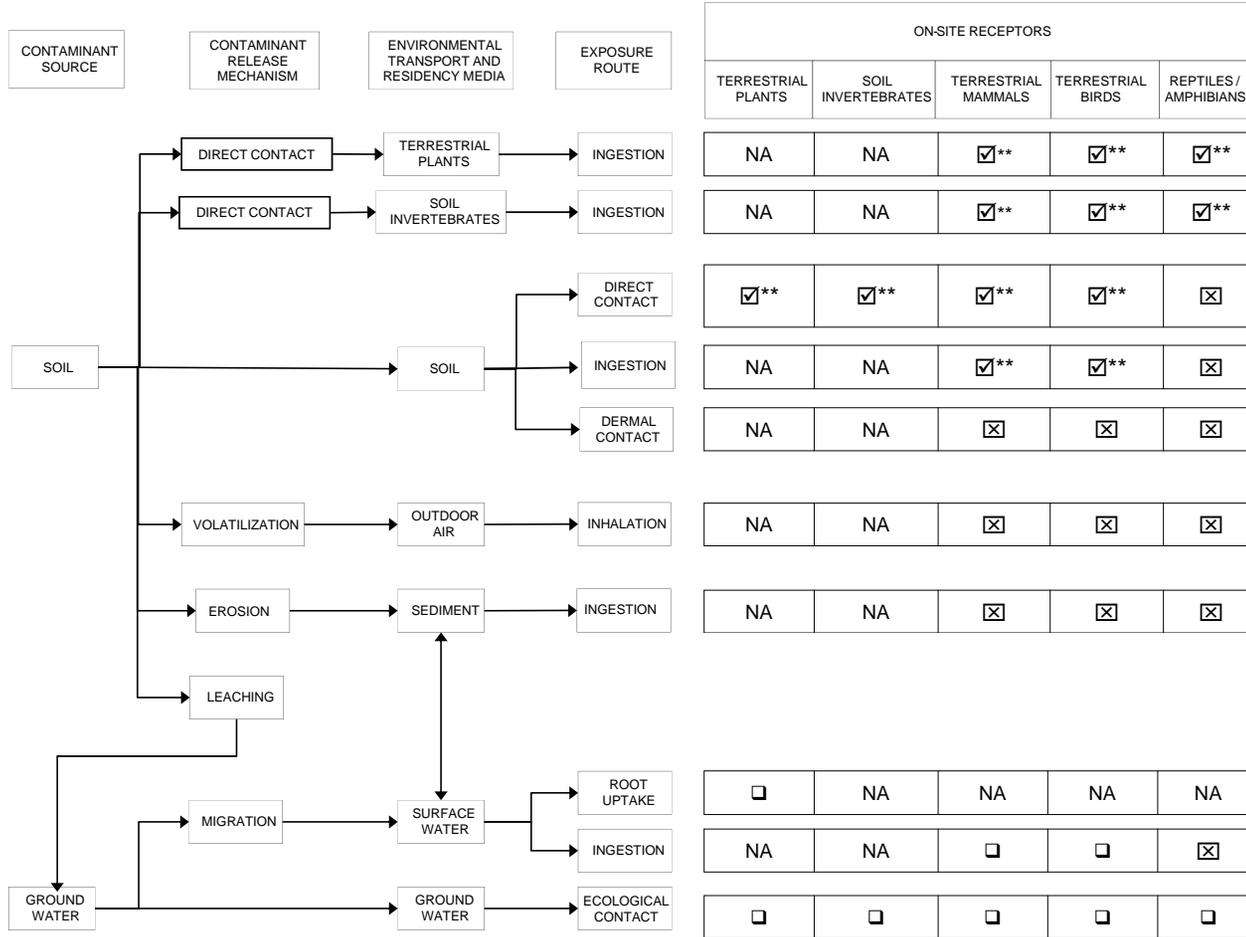


CAD: SP

CKD: MZ

Conceptual Site Model – Terrestrial ERA

FIGURE 8a



Receptors of Concern
Plants and soil-dwelling organisms
Mammals and Birds (livestock and wildlife)
Reptiles and Amphibians

Legend

** Soil-related pathways associated with direct contact exposure are complete and considered in the ERA, however, not evaluated in the ERA. All other soil pathways were not retained in the ERA.

- ☑ Exposure pathway is complete and retained in the ERA
- ☒ Exposure pathway is complete and not retained in the ERA (considered negligible)
- ☐ Exposure pathway is incomplete
- NA Exposure pathway not applicable

Date: July 2018

Project Number: 1663924

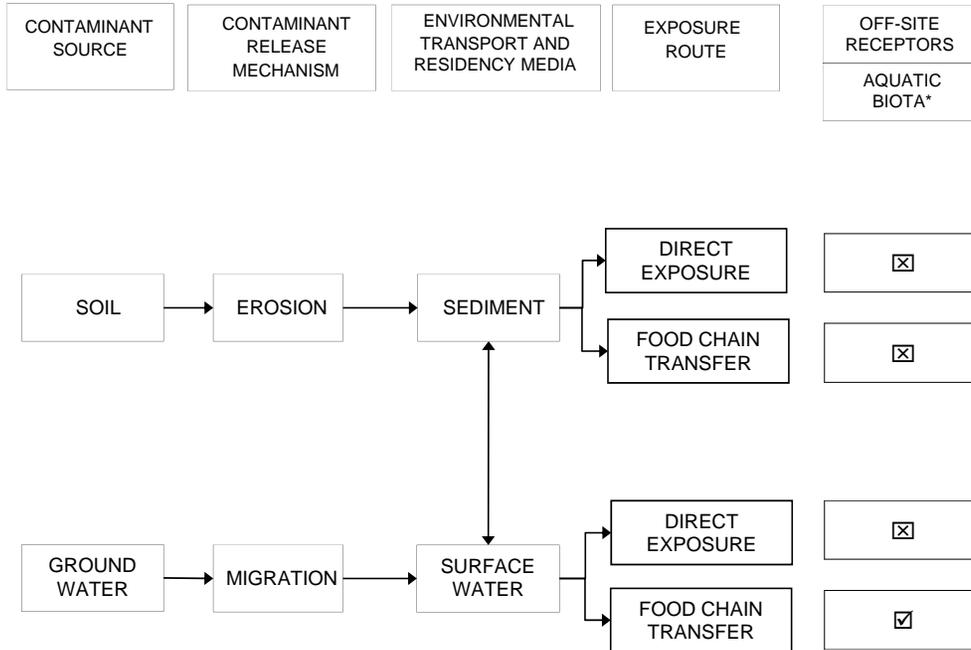


CAD: SP

CKD: MZ

Conceptual Site Model – Aquatic ERA

FIGURE 8b



Receptors of Concern

*Aquatic biota include aquatic plants, pelagic invertebrates, benthic invertebrates, fish, aquatic mammals and birds

Legend

- Exposure pathway is complete and retained in the ERA
- Exposure pathway is complete and not retained in the ERA
- Exposure pathway is incomplete (no COCs retained)
- NA Exposure pathway not applicable

Date: July 2018

Project Number: 1663924



CAD: SP

CKD: MZ



APPENDIX C

Screening Tables

Table C.1
Tier 1 Screening - Routine Chemistry Parameters in Groundwater
Bar U Ranch National Historic Site, Alberta
Public Works and Government Services Canada

Parameter	Hardness (CaCO ₃)	Dissolved Nitrate (NO ₃)	Nitrate plus Nitrite (N)	Dissolved Nitrite (NO ₂)	Total Dissolved Solids	Conductivity	pH	Alkalinity (PP as CaCO ₃)	Alkalinity (Total as CaCO ₃)	Bicarbonate (HCO ₃)	Carbonate (CO ₃)	Hydroxide (OH)	Dissolved Sulphate (SO ₄)	Dissolved Chloride (Cl)	Dissolved Nitrite (N)	Dissolved Nitrate (N)
Units	mg/L	mg/L	mg/L	mg/L	mg/L	µS/cm	pH	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
Health Canada CDWQG ^(a)	ng	45	ng	3	500	ng	6.5 - 8.5	ng	ng	ng	ng	ng	500	250	1	10
FIGQG ^(b)	ng	13	100	ng	3000	ng	6.5 - 9	ng	ng	ng	ng	ng	100	100	0.06	13
Selected Guideline ^(c)	ng	13 ^(b)	100 ^(b)	3 ^(a)	500 ^(a)	ng	6.5 - 8.5 ^(a)	ng	ng	ng	ng	ng	100 ^(b)	100 ^(b)	0.06 ^(b)	10 ^(a)
Maximum Measured Concentration ^(d)	280-7200	37	8.3	<0.33	12000	10000	7.47-8.09	< 0.50	880	1100	< 0.50	< 0.50	8390	130	<0.050	8.3
Location of Maximum Concentration	All locations	MW7	MW7	MW1, MW2, MW6, MW9, MW12, MW17	MW7, MW8	MW7	MW1, MW16	MW1-MW3, MW6-MW9, MW12, MW17	MW6	MW6	MW1-MW3, MW6-MW9, MW12, MW17	MW1-MW3, MW6-MW9, MW12, MW17	MW8	MW7	MW1, MW3, MW4, MW6-MW10, MW12-MW14, MW16	MW7
Retain as a COC?	No	Yes	No	No	No ^(e)	No ^(e)	No	No	No ^(e)	No ^(e)	No	No	Yes	No (see text)	No	No

Notes:

(a) Health Canada Guidelines for Canadian Drinking Water Quality (CDWQG), October 2014.

(b) Federal Contaminated Sites Action Plan (FCSAP) Federal Interim Groundwater Quality Guidelines (FIGQG) for Federal Contaminated Sites. Table 1: minimum Tier 2 Guidelines for fine-grained soil and agricultural land use, with the Marine Life pathway excluded, June 2016, version 4.

(c) The selected guideline was the lowest between the Health Canada Canadian Drinking Water Quality Guideline (CDWQG) and the Federal Interim Groundwater Quality Guideline (FIGQG).

(d) Maximum detectable concentration shown in brackets

(e) Parameter is not considered a contaminant and is not typically considered through risk assessment

COC - Contaminant of concern

mg/L - milligrams per litre

µS/cm - microSiemens per centimeter

< - less than reportable detection limit

ng - no guideline

BOLD indicates an exceedance of the selected guideline

Table should be read in conjunction with accompanying report.

Table C.2
Tier 1 Screening - Dissolved Metals in Groundwater
Bar U Ranch National Historic Site, Alberta
Public Works and Government Services Canada

Parameter	Dissolved Aluminum (Al)	Dissolved Antimony (Sb)	Dissolved Arsenic (As)	Dissolved Barium (Ba)	Dissolved Beryllium (Be)	Dissolved Boron (B)	Dissolved Cadmium (Cd)	Dissolved Calcium (Ca)	Dissolved Chromium (Cr)	Dissolved Cobalt (Co)	Dissolved Copper (Cu)	Dissolved Iron (Fe)
Units	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
Health Canada CDWQG ^(a)	0.1	0.006	0.010	1.0	ng	5	0.005	ng	0.05	ng	1.0	0.3
FIGQG ^(b)	0.1	2	0.005	2.9	0.0053	0.5	0.00037	ng	0.0089	0.05	0.004	0.3
Selected Guideline ^(c)	0.1 ^(a)	0.006 ^(a)	0.005 ^(b)	1.0 ^(a)	0.0053 ^(b)	0.5 ^(b)	0.00037 ^(a)	ng	0.0089 ^(b)	0.05 ^(b)	0.004 ^(b)	0.3 ^{(a)(b)}
Maximum Measured Concentration ^(f)	0.1	0.0014	0.0057	0.256	<0.0010	0.21	0.031	680	0.007	0.0067	0.012	3
Location of Maximum Concentration	MW4	MW4	MW6	MW6	MW1-MW3, MW6, MW7, MW9, MW17	MW9	MW17	MW3	MW10	MW8, MW9	MW8, MW10	MW6
Retain as a COC?	No	No	No (see text)	No	No	No	Yes	No (see text)	No	No	Yes	Yes

Notes:

(a) Health Canada Guidelines for Canadian Drinking Water Quality, October 2014.

(b) Federal Contaminated Sites Action Plan (FCSAP) Federal Interim Groundwater Quality Guidelines (FIGQGs) for Federal Contaminated Sites, Table 1: minimum Tier 2 Guidelines for fine-grained soil and agricultural land use, with the Marine Life pathway excluded, June 2016, version 4.

(c) The selected guideline was the lowest between the Health Canada Canadian Drinking Water Quality Guideline (CDWQG) and the Federal Interim Groundwater Quality Guideline (FIGQG).

(e) Maximum Concentration is based on old data (i.e., 2004-2008). Concentrations from subsequent, more recent sampling events (i.e., 2014-2016) do not show exceedances in this monitoring well; as such, the parameter was not retained as a COC.

(f) Maximum detectable concentration shown in brackets

FCSAP guidelines for aluminum (considering pH), and cadmium, copper, lead and nickel (considering hardness) were determined based on FCSAP guidance, including reference to CCME calculations. For aluminum, pH >6.5 at the Site, as such guideline of 100 ug/L was used. For hardness dependent parameters, CCME calculations were conducted using the CCME online calculator using the minimum hardness of all groundwater quality samples collected at the Site (i.e., 280 mg/L). Source: Canadian Council of Ministers of the Environment (CCME) Canadian Water Quality Guidelines for the Protection of Freshwater Aquatic Life (FAL), current to 2017.

RDL - reported detection limit

COC - Contaminant of concern

mg/L - milligrams per litre

< - less than RDL

ng - no guideline

BOLD - indicates an exceedance of the selected guideline

Table should be read in conjunction with accompanying report.

Table C.2
Tier 1 Screening - Dissolved Metals in Groundwater
Bar U Ranch National Historic Site, Alberta
Public Works and Government Services Canada

Parameter	Dissolved Lead (Pb)	Dissolved Lithium (Li)	Dissolved Magnesium (Mg)	Dissolved Manganese (Mn)	Dissolved Molybdenum (Mo)	Dissolved Nickel (Ni)	Dissolved Phosphorus (P)	Dissolved Potassium (K)	Dissolved Selenium (Se)	Dissolved Silicon (Si)	Dissolved Silver (Ag)	Dissolved Sodium (Na)
Units	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
Health Canada CDWQG ^(a)	0.010	ng	ng	0.05	ng	ng	ng	ng	0.05	ng	ng	200
FIGQG ^(b)	0.007	ng	ng	0.2	0.073	0.150	ng	ng	0.001	ng	0.00025	ng
Selected Guideline ^(c)	0.007 ^(b)	ng	ng	0.05 ^(a)	0.073 ^(b)	0.150 ^(b)	ng	ng	0.001 ^(b)	ng	0.00025 ^(b)	200 ^(a)
Maximum Measured Concentration ^(f)	<0.005 (0.0016)	0.13	1500	3.2	0.003	0.057	0.11	28	0.0502	5.4	<0.005 (0.00046)	1130
Location of Maximum Concentration	MW1, MW3, MW4, MW6, MW16	MW7	MW7, MW8	MW8	MW9	MW4	MW7	MW3	MW10	MW9	MW7	MW8
Retain as a COC?	No	Yes	Yes	Yes	No	No	Yes	Yes	No ^(e)	Yes	No ^(e)	Yes

Notes:

(a) Health Canada Guidelines for Canadian Drinking Water Quality, October 2014.

(b) Federal Contaminated Sites Action Plan (FCSAP) Federal Interim Groundwater Quality Guidelines (FIGQGs) for Federal Contaminated Sites, Table 1: minimum Tier 2 Guidelines for fine-grained soil and agricultural land use, with the Marine Life pathway excluded, June 2016, version 4.

(c) The selected guideline was the lowest between the Health Canada Canadian Drinking Water Quality Guideline (CDWQG) and the Federal Interim Groundwater Quality Guideline (FIGQG).

(e) Maximum Concentration is based on old data (i.e., 2004-2008). Concentrations from subsequent, more recent sampling events (i.e., 2014-2016) do not show exceedances in this monitoring well; as such, the parameter was not retained as a COC.

(f) Maximum detectable concentration shown in brackets

FCSAP guidelines for aluminum (considering pH), and cadmium, copper, lead and nickel (considering hardness) were determined based on FCSAP guidance, including reference to CCME calculations. For aluminum, pH >6.5 at the Site, as such guideline of 100 ug/L was used. For hardness dependent parameters, CCME calculations were conducted using the CCME online calculator using the minimum hardness of all groundwater quality samples collected at the Site (i.e., 280 mg/L). Source: Canadian Council of Ministers of the Environment (CCME) Canadian Water Quality Guidelines for the Protection of Freshwater Aquatic Life (FAL), current to 2017.

RDL - reported detection limit

COC - Contaminant of concern

mg/L - milligrams per litre

< - less than RDL

ng - no guideline

BOLD - indicates an exceedance of the selected guideline

Table should be read in conjunction with accompanying report.

Table C.2
Tier 1 Screening - Dissolved Metals in Groundwater
Bar U Ranch National Historic Site, Alberta
Public Works and Government Services Canada

Parameter	Dissolved Strontium (Sr)	Dissolved Sulphur (S)	Dissolved Thallium (Tl)	Dissolved Tin (Sn)	Dissolved Titanium (Ti)	Dissolved Uranium (U)	Dissolved Vanadium (V)	Dissolved Zinc (Zn)
Units	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
Health Canada CDWQG ^(a)	ng	ng	ng	ng	ng	0.02	ng	5
FIGQG ^(b)	ng	ng	0.0008	ng	0.1	0.01	0.1	0.03
Selected Guideline ^(c)	ng	ng	0.0008 ^(b)	ng	0.1 ^(b)	0.01 ^(b)	0.1 ^(b)	0.03 ^(b)
Maximum Measured Concentration ^(f)	11	2800	0.00034	<0.0010	<0.0010	0.1	0.0023	0.052
Location of Maximum Concentration	MW7	MW7	MW8	MW1-MW3, MW6, MW7, MW9, MW17	MW1-MW3, MW6, MW7, MW9, MW17	MW7	MW9	MW3
Retain as a COC?	Yes	Yes	No	No	No	Yes	No	No (see text)

Notes:

(a) Health Canada Guidelines for Canadian Drinking Water Quality, October 2014.

(b) Federal Contaminated Sites Action Plan (FCSAP) Federal Interim Groundwater Quality Guidelines (FIGQGs) for Federal Contaminated Sites, Table 1: minimum Tier 2 Guidelines for fine-grained soil and agricultural land use, with the Marine Life pathway excluded, June 2016, version 4.

(c) The selected guideline was the lowest between the Health Canada Canadian Drinking Water Quality Guideline (CDWQG) and the Federal Interim Groundwater Quality Guideline (FIGQG).

(e) Maximum Concentration is based on old data (i.e., 2004-2008). Concentrations from subsequent, more recent sampling events (i.e., 2014-2016) do not show exceedances in this monitoring well; as such, the parameter was not retained as a COC.

(f) Maximum detectable concentration shown in brackets

FCSAP guidelines for aluminum (considering pH), and cadmium, copper, lead and nickel (considering hardness) were determined based on FCSAP guidance, including reference to CCME calculations. For aluminum, pH >6.5 at the Site, as such guideline of 100 ug/L was used. For hardness dependent parameters, CCME calculations were conducted using the CCME online calculator using the minimum hardness of all groundwater quality samples collected at the Site (i.e., 280 mg/L). Source: Canadian Council of Ministers of the Environment (CCME) Canadian Water Quality Guidelines for the Protection of Freshwater Aquatic Life (FAL), current to 2017.

RDL - reported detection limit

COC - Contaminant of concern

mg/L - milligrams per litre

< - less than RDL

ng - no guideline

BOLD - indicates an exceedance of the selected guideline

Table should be read in conjunction with accompanying report.

Table C.3
Tier 1 Screening - Polycyclic Aromatic Hydrocarbons in Groundwater
Bar U Ranch National Historic Site, Alberta
Public Works and Government Services Canada

Parameter	Acenaphthene	Acenaphthylene	Acridine	Anthracene	Benzo[a]anthracene	Benzo[b,j]fluoranthene	Benzo[k]fluoranthene	Benzo[ghi]perylene	Benzo[c]phenanthrene	Benzo[a]pyrene	Benzo[e]pyrene	Chrysene	Dibenzo[ef,h]anthracene	Fluoranthene	Fluorene	Indeno[1,2,3-cd]pyrene	2-Methylnaphthalene	Naphthalene	Perylene	Phenanthrene	Pyrene	Quinoline
Units	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
Health Canada CDWQG ^(a)	ng	ng	ng	ng	ng	ng	ng	ng	ng	0.00001	ng	ng	ng	ng	ng	ng	ng	ng	ng	ng	ng	ng
FIGQG ^(b)	0.0058	0.046	ng	0.000012	0.000018	0.00048	0.00048	0.00021	ng	0.000017	ng	0.0014	0.00028	0.00004	0.003	0.00023	0.18	0.0011	ng	0.0004	0.000025	0.0034
Selected Guideline ^(c)	0.0058 ^(b)	0.046 ^(b)	ng	0.000012 ^(b)	0.000018 ^(b)	0.00048 ^(b)	0.00048 ^(b)	0.00021 ^(b)	ng	0.00001 ^(b)	ng	0.0014 ^(b)	0.00028 ^(b)	0.00004 ^(b)	0.003 ^(b)	0.00023 ^(b)	0.18 ^(b)	0.0011 ^(b)	ng	0.0004 ^(b)	0.000025 ^(b)	0.0034 ^(b)
Maximum Measured Concentration ^(d)	<0.00025 (0.00002)	<0.00025	<0.00050	<0.0002 (0.00002)	<0.0002 (0.00002)	<0.0002 (0.000051)	<0.0002 (0.000013)	<0.0002 (0.000038)	<0.00013	0.000024	<0.00013	<0.0002 (0.000078)	<0.0002 (0.000012)	<0.0002 (0.000062)	<0.0002 (0.000099)	<0.0002 (0.000015)	<0.00010	<0.00025 (0.000178)	<0.00013	0.000346	<0.0002 (0.000116)	<0.00050
Location of Maximum Concentration	MW14	MW2, MW12	MW2, MW12	MW1	MW6	MW6	MW6, MW12	MW6	MW2, MW12	MW6	MW2, MW12	MW6	MW6, MW12	MW6	MW6	MW6	MW1-MW3, MW5-MW9, MW12, MW17	MW6	MW2, MW12	MW6	MW6	MW2, MW12
Retain as a COC?	No	No	No ^(e)	No (see text)	No ^(f)	No	No	No	No ^(e)	No ^(f)	No ^(e)	No	No	No ^(f)	No	No	No	No ^(e)	No	No ^(f)	No	No

Notes:
(a) Health Canada Guidelines for Canadian Drinking Water Quality, October 2014.
(b) Federal Contaminated Sites Action Plan (FCSAP) Federal Interim Groundwater Quality Guidelines (FIGQGs) for Federal Contaminated Sites. Table 1: minimum Tier 2 Guidelines for fine-grained soil and agricultural land use, with the Marine Life pathway excluded, June 2016, version 4.
(c) The selected guideline was the lowest between the Health Canada Canadian Drinking Water Quality Guideline (CDWQG) and the Federal Interim Groundwater Quality Guideline (FIGQG).
(d) Maximum detectable concentration shown in brackets
(e) Concentrations from all samples were not detected above the reporting detection limit; as such, the parameter was not retained as a COC even though no guidelines were available.
(f) Maximum Concentration is based on old data (i.e., 2004-2008). Concentrations from subsequent, more recent sampling events (i.e., 2014-2016) do not show exceedances in this monitoring well; as such, the parameter was not retained as a COC.
COC - Contaminant of concern
mg/L - milligrams per litre
< - less than reportable detection limit
ng - no guideline
BOLD indicates an exceedance of the selected guideline
Table should be read in conjunction with accompanying report.

Table C.4
Wilcoxon Rank Sum Tests (Routine Chemistry Parameters in Groundwater)
Bar U Ranch National Historic Site, Alberta
Public Works and Government Services Canada

Dissolved Nitrate (NO ₃)										Dissolved Sulphate (SQ)									
Dataset 1 (exposure)	Dataset 2 (background)	Combined and sorted	Rank (average)	W ⁽¹⁾	N1 ⁽²⁾	N2 ⁽³⁾	Z ⁽⁴⁾	Within background range?	Retain as a COC?	Dataset 1 (exposure)	Dataset 2 (background)	Combined and sorted	Rank (average)	W ⁽¹⁾	N1 ⁽²⁾	N2 ⁽³⁾	Z ⁽⁴⁾	Within background range?	Retain as a COC?
0.23	0.43	0.073	1	195	18	5	-1.56525	Yes	No	4670	8100	42	1	803	38	5	-1.25026	Yes	No
0.11	0.37	0.11	3							2800	7400	47	2						
0.33	0.26	0.11	3							2700	1400	184	3						
0.27	7.1	0.11	3							2700	1000	647	4						
0.88	2.2	0.12	5							790	15000	656	5						
1.4		0.15	6							1500		790	6						
0.25		0.22	7							1900		840	7						
0.073		0.23	8							1510		870	8						
37		0.25	9							2140		1000	9						
32		0.26	10							2100		1030	10						
0.22		0.27	11							4200		1100	11						
0.11		0.29	12							5700		1200	12.5						
0.15		0.33	13							4220		1200	12.5						
0.41		0.37	14							1030		1400	14						
0.89		0.41	15							1200		1500	15.5						
0.12		0.43	16							1600		1500	15.5						
0.11		0.58	17							1500		1510	17						
0.29		0.59	18							3330		1600	18.5						
		1.4	19							8600		1600	18.5						
		2.2	20							8300		1900	20						
		7.1	21							6300		2100	21						
		32	22							8390		2140	22						
		37	23							8600		2150	23						
										8200		2700	24.5						
										7300		2700	24.5						
										2150		2800	26						
										840		3330	27						
										1600		3900	28						
										3900		4200	29						
										7120		4220	30						
										656		4670	31						
										870		5700	32						
										1200		6300	33						
										1100		6600	34.5						
										647		6600	34.5						
										184		7120	36						
										47		7300	37						
										42		7400	38						
												8100	39						
												8200	40						
												8300	41						
												8390	42						
												15000	43						

Notes:

Calculation equation is described by PWGSC (2011)

⁽¹⁾ W - sum of ranks of dataset 1

⁽²⁾ N1 - sample size of dataset 1 (includes all discrete data). 1/2 the reportable detection limits are used for non-detect values. If a field duplicate sample was

⁽³⁾ N2 - sample size of dataset 2 (background samples)

⁽⁴⁾ Z - Wilcoxon rank-sum test z statistic (if z < -3 or z > 3, the parameter concentrations are not considered related to background concentrations)

References:

Public Works and Government Services Canada (PWGSC), 2011. Environment Canada Background Soil Quality Data, Newfoundland and Labrador (NL) (2005-09) Revision 2. Technical Assistance Document No. 1 (PWGSC TAD No.1), March 2

Prepared by: SP

Checked by: TR

**Wilcoxon Rank Sum Tests (Metals Parameters in Groundwater)
Bar U Ranch National Historic Site, Alberta
Public Works and Government Services Canada**

Dissolved Cadmium (Cd)									
Dataset 1 (exposure)	Dataset 2 (background)	Combined and sorted	Rank (average)	W ⁽¹⁾	N1 ⁽²⁾	N2 ⁽³⁾	Z ⁽⁴⁾	Within background range?	Retain as a COC?
0.00005	0.00026	0.00001	3.5	926	41	5	-1.32341	Yes	No
0.0005	0.00021	0.00001	3.5						
0.00001	0.00006	0.00001	3.5						
0.000038	0.000069	0.00001	3.5						
0.00005	0.00025	0.00001	3.5						
0.00005		0.00001	3.5						
0.00001		0.000027	7						
0.0002		0.00003	8						
0.000047		0.000032	9						
0.0005		0.000037	10						
0.0002		0.000038	11						
0.0005		0.000041	12						
0.000032		0.000047	13						
0.00025		0.00005	18.5						
0.00028		0.00005	18.5						
0.00005		0.00005	18.5						
0.0005		0.00005	18.5						
0.00005		0.00005	18.5						
0.0005		0.00005	18.5						
0.00001		0.00005	18.5						
0.00001		0.00005	18.5						
0.00001		0.00005	18.5						
0.00005		0.00005	18.5						
0.000053		0.000053	24						
0.000074		0.00006	25.5						
0.00006		0.00006	25.5						
0.0001		0.000069	27						
0.000027		0.000074	28						
0.00022		0.0001	29						
0.00086		0.0002	30.5						
0.00005		0.0002	30.5						
0.000037		0.00021	32						
0.00001		0.00022	33						
0.00005		0.00025	34.5						
0.00005		0.00025	34.5						
0.00003		0.00026	36						
0.000041		0.00028	37						
0.00005		0.0005	41						
0.0005		0.0005	41						
0.0005		0.0005	41						
0.031		0.0005	41						
		0.0005	41						
		0.0005	41						
		0.0005	41						
		0.00086	45						
		0.031	46						

**Wilcoxon Rank Sum Tests (Metals Parameters in Groundwater)
Bar U Ranch National Historic Site, Alberta
Public Works and Government Services Canada**

Dissolved Copper (Cu)									
Dataset 1 (exposure)	Dataset 2 (background)	Combined and sorted	Rank (average)	W ⁽¹⁾	N1 ⁽²⁾	N2 ⁽³⁾	Z ⁽⁴⁾	Within background range?	Retain as a COC?
0.0008	0.0034	0.0001	1.5	944	41	5	-0.70582	Yes	No
0.007	0.0025	0.0001	1.5						
0.00049	0.0018	0.00033	3						
0.0012	0.0029	0.00049	4						
0.00068	0.0077	0.0005	5						
0.0017		0.00068	6						
0.0024		0.0008	7						
0.00084		0.00084	8						
0.0013		0.0011	9						
0.005		0.0012	10						
0.004		0.0013	11.5						
0.002		0.0013	11.5						
0.0021		0.0017	13.5						
0.0037		0.0017	13.5						
0.0075		0.0018	15						
0.0025		0.002	17						
0.008		0.002	17						
0.0017		0.002	17						
0.002		0.0021	20						
0.0001		0.0021	20						
0.0001		0.0021	20						
0.00033		0.0024	22						
0.005		0.0025	24						
0.0077		0.0025	24						
0.0082		0.0025	24						
0.0065		0.0027	26						
0.012		0.0029	27						
0.0013		0.003	28.5						
0.0043		0.003	28.5						
0.0037		0.0034	30						
0.006		0.0037	31.5						
0.0027		0.0037	31.5						
0.0021		0.004	33						
0.012		0.0043	34						
0.003		0.005	35.5						
0.0021		0.005	35.5						
0.0025		0.006	37						
0.003		0.0065	38						
0.002		0.007	39						
0.0005		0.0075	40						
0.0011		0.0077	41.5						
		0.0077	41.5						
		0.008	43						
		0.0082	44						
		0.012	45.5						
		0.012	45.5						

**Wilcoxon Rank Sum Tests (Metals Parameters in Groundwater)
Bar U Ranch National Historic Site, Alberta
Public Works and Government Services Canada**

Dissolved Iron (Fe)									
Dataset 1 (exposure)	Dataset 2 (background)	Combined and sorted	Rank (average)	W ⁽¹⁾	N1 ⁽²⁾	N2 ⁽³⁾	Z ⁽⁴⁾	Within background range?	Retain as a COC?
0.015	0.03	0.0025	3.5	939	41	5	-0.865	Yes	No
0.117	0.03	0.0025	3.5						
0.21	0.26	0.0025	3.5						
0.56	0.22	0.0025	3.5						
0.068	3.6	0.0025	3.5						
0.015		0.0025	3.5						
1.5		0.006	7.5						
0.33		0.006	7.5						
0.068		0.008	9						
0.016		0.015	10.5						
0.089		0.015	10.5						
0.006		0.016	12						
0.1		0.03	16.5						
0.54		0.03	16.5						
0.03		0.03	16.5						
0.03		0.03	16.5						
2.88		0.03	16.5						
0.07		0.03	16.5						
1.17		0.03	16.5						
3		0.03	16.5						
1.8		0.068	21.5						
1.3		0.068	21.5						
0.0025		0.07	23						
0.03		0.077	24						
0.72		0.085	25						
0.03		0.089	26						
0.0025		0.1	27						
0.085		0.117	28						
0.74		0.17	29						
0.17		0.21	30						
0.0025		0.22	31						
0.43		0.26	32						
0.5		0.33	33						
0.0025		0.43	34						
0.008		0.5	35						
0.077		0.54	36						
0.03		0.56	37						
0.0025		0.72	38						
0.006		0.74	39						
0.0025		1.17	40						
0.03		1.3	41						
		1.5	42						
		1.8	43						
		2.88	44						
		3	45						
		3.6	46						

**Wilcoxon Rank Sum Tests (Metals Parameters in Groundwater)
Bar U Ranch National Historic Site, Alberta
Public Works and Government Services Canada**

Dissolved Manganese (Mn)									
Dataset 1 (exposure)	Dataset 2 (background)	Combined and sorted	Rank (average)	$W^{(1)}$	$N1^{(2)}$	$N2^{(3)}$	$Z^{(4)}$	Within background range?	Retain as a COC?
0.0025	0.98	0.0005	1.5	945.5	41	5	-0.63524	Yes	No
2.74	1.9	0.0005	1.5						
1.8	0.05	0.002	4						
1.9	0.02	0.002	4						
1.7	2.5	0.002	4						
0.0025		0.0025	6.5						
0.52		0.0025	6.5						
0.64		0.008	8.5						
0.62		0.008	8.5						
0.671		0.02	10						
1.46		0.022	11						
0.152		0.05	12						
0.13		0.07	13						
0.15		0.075	14						
0.083		0.083	15						
0.008		0.093	16						
2.63		0.113	17						
0.934		0.123	18						
0.282		0.13	19						
0.19		0.15	20						
0.26		0.152	21						
0.18		0.18	22						
0.0005		0.183	23						
0.002		0.19	24						
0.002		0.26	25						
0.002		0.282	26						
0.183		0.38	27						
2.4		0.52	28						
2.9		0.62	29						
3.2		0.64	30						
0.022		0.671	31						
2.2		0.934	32						
1.2		0.98	33						
0.0005		1.2	34						
0.123		1.46	35						
0.38		1.7	36						
0.075		1.8	37						
0.093		1.9	38.5						
0.113		1.9	38.5						
0.008		2.2	40						
0.07		2.4	41						
		2.5	42						
		2.63	43						
		2.74	44						
		2.9	45						
		3.2	46						

Table C.5
Wilcoxon Rank Sum Tests (Metals Parameters in Groundwater)
Bar U Ranch National Historic Site, Alberta
Public Works and Government Services Canada

Notes:

Calculation equation is described by PWGSC (2011)

⁽¹⁾ W - sum of ranks of dataset 1

⁽²⁾ N1 - sample size of dataset 1 (includes all discrete data). 1/2 the reportable detection limits are used for non-detect values. If a field duplicate sample was available, only the higher of the original or the duplicate was used.

⁽³⁾ N2 - sample size of dataset 2 (background samples)

⁽⁴⁾ Z - Wilcoxon rank-sum test z statistic (if $z < -3$ or $z > 3$, the parameter concentrations are not considered related to background concentrations)

References:

Public Works and Government Services Canada (PWGSC), 2011. Environment Canada Background Soil Quality Data, Newfoundland and Labrador (NL) (2005-09) Revision 2. Technical Assistance Document No. 1 (PWGSC TAD No.1), March 2011

Prepared by: SP

Checked by: TR

Table C.6
Wilcoxon Rank Sum Tests - Summary in Groundwater
Bar U Ranch National Historic Site, Alberta
Public Works and Government Services Canada

Parameter	W ⁽¹⁾	N1 ⁽²⁾	N2 ⁽³⁾	Z ⁽⁴⁾	Within background range?	Retain as a COC?
Dissolved nitrate (NO ₃)	195	18	5	-1.57	Yes	No
Dissolved sulphate (SO ₄)	803	38	5	-1.25	Yes	No
Metals						
Cadmium	926	41	5	-1.32	Yes	No
Copper	944	41	5	-0.71	Yes	No
Iron	939	41	5	-0.86	Yes	No
Lithium	155	16	5	-1.73	Yes	No
Magnesium	553	31	5	-0.96	Yes	No
Manganese	946	41	5	-0.64	Yes	No
Phosphorous	174	16	5	-0.17	Yes	No
Potassium	548	31	5	-1.19	Yes	No
Silicon	155	16	5	-1.78	Yes	No
Sodium	556	31	5	-0.80	Yes	No
Strontium	165.5	16	5	-0.87	Yes	No
Sulphur	170	16	5	-0.54	Yes	No
Uranium	772	35	5	2.23	Yes	No

Notes:

COC - Contaminant of concern

⁽¹⁾ W - sum of ranks of dataset 1

⁽²⁾ N1 - sample size of dataset 1 (includes all discrete data). 1/2 the reportable detection limits are used for non-detect values. If a field duplicate sample was available, only the higher of the original or the

⁽³⁾ N2 - sample size of dataset 2 (background samples)

⁽⁴⁾ Z - Wilcoxon rank-sum test z statistic (if $z < -3$ or $z > 3$, the parameter concentrations are not considered related to background concentrations)

Bold and shaded Z statistic is outside range between -3 and 3

References:

Public Works and Government Services Canada (PWGSC), 2011. Environment Canada Background Soil Quality Data, Newfoundland and Labrador (NL) (2005-09) Revision 2. Technical Assistance Document No. 1 (PWGSC TAD No.1), March 2011

Prepared by: SP

Checked by: TR

Table C.7
Tier 1 Screening - Routine Chemistry Parameters in Surface Water
Bar U Ranch National Historic Site, Alberta
Public Works and Government Services Canada

Parameters	Hardness (CaCO3)	Dissolved Nitrate (NO3)	Nitrate plus Nitrite (N)	Dissolved Nitrite (NO2)	Total Dissolved Solids	Conductivity	pH	Alkalinity (PP as CaCO3)	Alkalinity (Total as CaCO3)	Bicarbonate (HCO3)	Carbonate (CO3)	Hydroxide (OH)	Dissolved Sulphate (SO4)	Dissolved Chloride (Cl)	Dissolved Nitrite (N)	Dissolved Nitrate (N)
Units	mg/L	mg/L	mg/L	mg/L	mg/L	uS/cm	pH	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
CCME CWQG for the Protection of FAL ^(a)	ng	13	ng	0.06	ng	ng	6.5 - 9	ng	ng	ng	ng	ng	ng	120	ng	ng
CCME CWQG for the Protection of Agricultural Water Uses ^(b)	ng	ng	100	10	3,000	ng	ng	ng	ng	ng	ng	ng	1,000	ng	ng	ng
Selected Guideline	ng	13 ^(a)	100 ^(b)	0.06 ^(a)	3,000 ^(b)	ng	6.5 - 9 ^(a)	ng	ng	ng	ng	ng	1,000 ^(b)	120 ^(a)	ng	ng
Maximum Measured Concentration	220-240	0.19	0.043	0.04	270	480	8.19-8.3	< 0.50	220	260	< 0.50	< 0.50	56	1.7	0.012	0.043
Location of Maximum Concentration	All locations	SW15-02	SW15-02	SW16-07-02	SW16-07-02	SW15-02	SW16-06-02	All locations	SW15-02	SW15-02	All locations	All locations	SW16-07-02	SW16-02-04	SW16-07-02	SW15-02
Retain as a COC?	No ^(c)	No	No	No	No	No ^(c)	No	No	No ^(c)	No ^(c)	No	No	No	No	Yes	Yes

Notes:

- (a) Canadian Council of Ministers of the Environment (CCME) Canadian Water Quality Guidelines for the Protection of Freshwater Aquatic Life (FAL), current to 2017.
 - (b) Canadian Council of Ministers of the Environment (CCME) Canadian Water Quality Guidelines for the Protection of Agricultural (Ag) Water Uses (Irrigation and Livestock Water), current to 2017.
 - (c) Parameter not considered a contaminant and is therefore not typically retained for risk assessment
- CCME AG guideline for chloride was based on foliar damage for crops that were considered likely to be produced in this climate zone (including alfalfa, barley, corn, cucumbers, cauliflower, sugarbeets, sunflower)
- COC - Contaminant of concern
- mg/L - milligrams per litre
- µS/cm - microSiemens per centimeter
- < - less than reportable detection limit
- ng - no guideline

BOLD indicates an exceedance of the selected guideline

Table should be read in conjunction with accompanying report.

Prepared by: HT/AB

Checked by: TR

Table C.8
Tier 1 Screening - Total Metals in Surface Water
Bar U Ranch National Historic Site, Alberta
Public Works and Government Services Canada

Parameter	Total Aluminum (Al)	Total Antimony (Sb)	Total Arsenic (As)	Total Barium (Ba)	Total Beryllium (Be)	Total Boron (B)	Total Cadmium (Cd)	Total Calcium (Ca)	Total Chromium (Cr)	Total Cobalt (Co)	Total Copper (Cu)	Total Iron (Fe)	Total Lead (Pb)	Total Lithium (Li)	Total Magnesium (Mg)	Total Manganese (Mn)	Total Molybdenum (Mo)	Total Nickel (Ni)	Total Phosphorus (P)	Total Potassium (K)	Total Selenium (Se)	Total Silicon (Si)	Total Silver (Ag)	Total Sodium (Na)	Total Strontium (Sr)	Total Sulphur (S)	Total Thallium (Tl)	Total Tin (Sn)	Total Titanium (Ti)	Total Uranium (U)	Total Vanadium (V)	Total Zinc (Zn)	
Units	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	ug/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	
CCME CWQG for the Protection of FAL^(a)	0.1	ng	0.005	ng	ng	1.5	0.0003	ng	ng	ng	0.004	0.3	0.007	ng	ng	ng	0.073	0.15	ng	ng	0.001	ng	0.00025	ng	ng	ng	ng	0.0008	ng	ng	0.015	ng	0.03
CCME CWQG for the Protection of Agricultural Water Uses^(b)	5	ng	0.025	ng	0.1	0.5	5.1	1,000	ng	0.05	0.2	5	0.1	2.5	ng	0.2	0.5	0.2	ng	ng	0.05	ng	ng	ng	ng	ng	ng	ng	ng	0.01	0.1	5	
Selected Guideline	0.1 ^(a)	ng	0.005 ^(a)	ng	0.1 ^(a)	0.5 ^(a)	0.09 ^(a)	1,000 ^(a)	ng	0.05 ^(a)	0.004 ^(a)	0.3 ^(a)	0.007 ^(a)	2.5 ^(a)	ng	0.2 ^(a)	0.073 ^(a)	0.15 ^(a)	ng	ng	0.001 ^(a)	ng	0.00025 ^(a)	ng	ng	ng	0.0008 ^(a)	ng	ng	0.01 ^(a)	0.1 ^(a)	0.03 ^(a)	
Maximum Measured Concentration^(c)	0.045	< 0.00060	0.00021	0.13	< 0.0010	< 0.020	< 0.020	76	0.01	< 0.00030	0.00043	<0.060	< 0.00020	< 0.020	17	< 0.0040	0.00087	0.0038	< 0.10	0.99	0.00072	2.6	< 0.00010	5.8	0.37	11	< 0.00020	< 0.0010	< 0.0010	0.00066	< 0.0010	< 0.0030	
Location of Maximum Concentration	SW16-08-02	All locations	SW15-02, SW16-06-03	All locations	All locations	All locations	All locations	SW15-02	SW16-02-02	All locations	SW15-02	SW15-02	All locations	All locations	SW15-02	All locations	SW16-02-02	SW16-02-02	All locations	SW16-02-01, SW16-06-01	SW15-02	SW16-02-01, SW16-02-03, SW16-07-01, SW16-08-01	All locations	SW16-02-01	SW15-02	SW15-02	All locations	All locations	All locations	SW15-02	All locations	All locations	
Retain as a COC?	No	No	No	Yes	No	No	No	No	Yes	No	No	No	No	No	Yes	No	No	No	No	Yes	No	Yes	No	Yes	Yes	Yes	No	No	No	No	No	No	

Notes:
 (a) Canadian Council of Ministers of the Environment (CCME) Canadian Water Quality Guidelines for the Protection of Freshwater Aquatic Life (FAL), current to 2017. A pH value of >6.5 was considered for aluminum, and a minimum hardness value of 220 mg/L was considered for cadmium, copper, lead and nickel.
 (b) Canadian Council of Ministers of the Environment (CCME) Canadian Water Quality Guidelines for the Protection of Agricultural (Ag) Water Uses (Irrigation and Livestock Water), current to 2017.
 (c) Maximum detectable concentration shown in brackets
 COC - Contaminant of concern
 mg/L - milligrams per litre
 < - less than reportable detection limit
 ng - no guideline
BOLD indicates an exceedance of the selected guideline
 Table should be read in conjunction with accompanying report.

Table C.9
Tier 1 Screening - Polycyclic Aromatic Hydrocarbons in Surface Water
Bar U Ranch National Historic Site, Alberta
Public Works and Government Services Canada

Parameter	Acenaphthene	Acenaphthylene	Acridine	Anthracene	Benzo[<i>a</i>]anthracene	Benzo[<i>b</i>]fluoranthene	Benzo[<i>k</i>]fluoranthene	Benzo[<i>h</i>]perylene	Benzo[<i>ghi</i>]perylene	Benzo[<i>a</i>]pyrene	Benzo[<i>ghi</i>]perylene	Chrysene	Dibenzo[<i>a,h</i>]anthracene	Fluoranthene	Fluorene	Indeno[1,2,3- <i>cd</i>]pyrene	2-Methylnaphthalene	Naphthalene	Perylene	Phenanthrene	Pyrene	Quinoline	B[<i>a</i>]P Equivalency
Units	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
CCME CWQG for the Protection of FAL ^(a)	0.0058	ng	0.0044	0.000012	0.000018	ng	ng	ng	ng	0.000015	ng	ng	ng	0.00004	0.003	ng	ng	0.0011	ng	0.0004	0.000025	0.0034	ng
CCME CWQG for the Protection of Agricultural Water Uses ^(b)	ng	ng	ng	ng	ng	ng	ng	ng	ng	ng	ng	ng	ng	ng	ng	ng	ng	ng	ng	ng	ng	ng	ng
Selected Guideline	0.0058 ^(a)	ng	0.0044 ^(a)	0.000012 ^(a)	0.000018 ^(a)	ng	ng	ng	ng	0.000015 ^(a)	ng	ng	ng	0.00004 ^(a)	0.003 ^(a)	ng	ng	0.0011 ^(a)	ng	0.0004 ^(a)	0.000025 ^(a)	0.0034 ^(a)	ng
Maximum Measured Concentration	<0.00010	<0.00010	<0.00020	<0.000010	<0.0000085	<0.0000085	<0.0000085	<0.0000085	<0.0000050	<0.0000075	<0.0000050	<0.0000085	<0.0000075	<0.000010	<0.000050	<0.0000085	<0.000010	<0.00010	<0.000050	<0.000050	<0.000020	<0.00020	<0.000010
Location of Maximum Concentration	All locations	All locations	All locations	All locations	All locations	All locations	All locations	All locations	All locations	All locations	All locations	All locations	All locations	All locations	All locations	All locations	All locations	All locations	All locations	All locations	All locations	All locations	All locations
Retain as a COC?	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No

Notes:
 (a) Canadian Council of Ministers of the Environment (CCME) Canadian Water Quality Guidelines for the Protection of Freshwater Aquatic Life (FAL), current to 2017.
 (b) Canadian Council of Ministers of the Environment (CCME) Canadian Water Quality Guidelines for the Protection of Agricultural (Ag) Water Uses (Irrigation and Livestock Water), current to 2017.
 COC - Contaminant of concern
 mg/L - milligrams per litre
 ng - no guideline
 < - less than reportable detection limit
BOLD indicates an exceedance of the selected guideline
 Table should be read in conjunction with accompanying report.

Prepared by: HT/AB
 Checked by: TR

Table C.10
Wilcoxon Rank Sum Tests (Routine Chemistry Parameters in Surface Water)
Bar U Ranch National Historic Site, Alberta
Public Works and Government Services Canada

Dissolved Nitrite (N)										Dissolved Nitrate (N)									
Dataset 1 (exposure)	Dataset 2 (background)	Combined and sorted	Rank (average)	W ⁽¹⁾	N1 ⁽²⁾	N2 ⁽³⁾	Z ⁽⁴⁾	Within background range?	Retain as a COC?	Dataset 1 (exposure)	Dataset 2 (background)	Combined and sorted	Rank (average)	W ⁽¹⁾	N1 ⁽²⁾	N2 ⁽³⁾	Z ⁽⁴⁾	Within background range?	Retain as a COC?
0.005	0.005	0.005	12	156	12	12	0.34641	Yes	No	0.043	0.038	0.005	9.5	147.5	12	12	-0.14434	Yes	No
0.005	0.005	0.005	12							0.005	0.14	0.005	9.5						
0.005	0.005	0.005	12							0.016	0.005	0.005	9.5						
0.005	0.005	0.005	12							0.005	0.019	0.005	9.5						
0.005	0.005	0.005	12							0.005	0.005	0.005	9.5						
0.005	0.005	0.005	12							0.005	0.005	0.005	9.5						
0.005	0.005	0.005	12							0.005	0.005	0.005	9.5						
0.005	0.005	0.005	12							0.005	0.005	0.005	9.5						
0.005	0.005	0.005	12							0.012	0.005	0.005	9.5						
0.012	0.005	0.005	12							0.005	0.005	0.005	9.5						
0.005	0.005	0.005	12							0.005	0.005	0.005	9.5						
0.005	0.005	0.005	12							0.005	0.005	0.005	9.5						
		0.005	12									0.005	9.5						
		0.005	12									0.005	9.5						
		0.005	12									0.005	9.5						
		0.005	12									0.005	9.5						
		0.005	12									0.005	9.5						
		0.005	12									0.005	9.5						
		0.005	12									0.005	9.5						
		0.005	12									0.012	19						
		0.005	12									0.016	20						
		0.005	12									0.019	21						
		0.005	12									0.038	22						
		0.005	12									0.043	23						
		0.012	24									0.14	24						

Notes:
 Calculation equation is described by PWGSC (2011)
⁽¹⁾ W - sum of ranks of dataset 1

⁽²⁾ N1 - sample size of dataset 1 (includes all discrete data). 1/2 the reportable detection limits are used for non-detect values. If a field duplicate sample was available, only the higher of the original or the duplicate was used.

⁽³⁾ N2 - sample size of dataset 2 (background samples)

⁽⁴⁾ Z - Wilcoxon rank-sum test z statistic (if z<-3 or z>3, the parameter concentrations are not considered related to background concentrations)

References:

Public Works and Government Services Canada (PWGSC), 2011. Environment Canada Background Soil Quality Data, Newfoundland and Labrador (NL) (2005-09) Revision 2. Technical Assistance Document No. 1 (PWGSC TAD No.1), March 2011

Prepared by: SP

Checked by: TR

**Table C.11
Wilcoxon Rank Sum Tests (Metals Parameters in Surface Water)
Bar U Ranch National Historic Site, Alberta
Public Works and Government Services Canada**

Dissolved Barium									
Dataset 1 (exposure)	Dataset 2 (background)	Combined and sorted	Rank (average)	$W^{(1)}$	$N1^{(2)}$	$N2^{(3)}$	$Z^{(4)}$	Within background range?	Retain as a COC?
0.13	0.14	0.12	1	127.5	12	12	-1.29904	Yes	No
0.13	0.13	0.13	11.5						
0.13	0.13	0.13	11.5						
0.13	0.13	0.13	11.5						
0.13	0.13	0.13	11.5						
0.13	0.13	0.13	11.5						
0.13	0.13	0.13	11.5						
0.12	0.15	0.13	11.5						
0.13	0.13	0.13	11.5						
0.13	0.15	0.13	11.5						
0.13	0.13	0.13	11.5						
0.13	0.13	0.13	11.5						
		0.13	11.5						
		0.13	11.5						
		0.13	11.5						
		0.13	11.5						
		0.13	11.5						
		0.13	11.5						
		0.13	11.5						
		0.13	11.5						
		0.13	11.5						
		0.14	22						
		0.15	23.5						
		0.15	23.5						

**Wilcoxon Rank Sum Tests (Metals Parameters in Surface Water)
Bar U Ranch National Historic Site, Alberta
Public Works and Government Services Canada**

Dissolved Chromium									
Dataset 1 (exposure)	Dataset 2 (background)	Combined and sorted	Rank (average)	W ⁽¹⁾	N1 ⁽²⁾	N2 ⁽³⁾	Z ⁽⁴⁾	Within background range?	Retain as a COC?
0.0005	0.0005	0.0005	9	153	12	12	0.173205	Yes	No
0.0005	0.0005	0.0005	9						
0.01	0.0057	0.0005	9						
0.0005	0.0005	0.0005	9						
0.0005	0.0005	0.0005	9						
0.0005	0.0079	0.0005	9						
0.001	0.0005	0.0005	9						
0.0005	0.0005	0.0005	9						
0.0018	0.0005	0.0005	9						
0.0005	0.0005	0.0005	9						
0.0005	0.0041	0.0005	9						
0.0023	0.0005	0.0005	9						
		0.0005	9						
		0.0005	9						
		0.0005	9						
		0.0005	9						
		0.0005	9						
		0.0005	9						
		0.001	18						
		0.0018	19						
		0.0023	20						
		0.0041	21						
		0.0057	22						
		0.0079	23						
		0.01	24						

**Table C.11
Wilcoxon Rank Sum Tests (Metals Parameters in Surface Water)
Bar U Ranch National Historic Site, Alberta
Public Works and Government Services Canada**

Dissolved Magnesium (Mg)									
Dataset 1 (exposure)	Dataset 2 (background)	Combined and sorted	Rank (average)	W ⁽¹⁾	N1 ⁽²⁾	N2 ⁽³⁾	Z ⁽⁴⁾	Within background range?	Retain as a COC?
17	17	13	7.5	161	12	12	0.635085	Yes	No
13	13	13	7.5						
13	13	13	7.5						
13	13	13	7.5						
13	14	13	7.5						
14	13	13	7.5						
14	13	13	7.5						
14	13	13	7.5						
13	13	13	7.5						
14	14	13	7.5						
13	13	13	7.5						
14	14	13	7.5						
		13	7.5						
		13	7.5						
		14	18.5						
		14	18.5						
		14	18.5						
		14	18.5						
		14	18.5						
		14	18.5						
		14	18.5						
		17	23.5						
		17	23.5						

**Table C.11
Wilcoxon Rank Sum Tests (Metals Parameters in Surface Water)
Bar U Ranch National Historic Site, Alberta
Public Works and Government Services Canada**

Dissolved Potassium (K)									
Dataset 1 (exposure)	Dataset 2 (background)	Combined and sorted	Rank (average)	$W^{(1)}$	$N1^{(2)}$	$N2^{(3)}$	$Z^{(4)}$	Within background range?	Retain as a COC?
17	17	13	7.5	161	12	12	0.635085	Yes	No
13	13	13	7.5						
13	13	13	7.5						
13	13	13	7.5						
13	14	13	7.5						
14	13	13	7.5						
14	13	13	7.5						
14	13	13	7.5						
13	13	13	7.5						
14	14	13	7.5						
13	13	13	7.5						
14	14	13	7.5						
		13	7.5						
		13	7.5						
		14	18.5						
		14	18.5						
		14	18.5						
		14	18.5						
		14	18.5						
		14	18.5						
		14	18.5						
		14	18.5						
		17	23.5						
		17	23.5						

**Wilcoxon Rank Sum Tests (Metals Parameters in Surface Water)
Bar U Ranch National Historic Site, Alberta
Public Works and Government Services Canada**

Dissolved Silicon									
Dataset 1 (exposure)	Dataset 2 (background)	Combined and sorted	Rank (average)	W ⁽¹⁾	N1 ⁽²⁾	N2 ⁽³⁾	Z ⁽⁴⁾	Within background range?	Retain as a COC?
2.4	2.4	2.4	2	126.5	12	12	-1.35677	Yes	No
2.6	2.6	2.4	2						
2.5	2.5	2.4	2						
2.5	2.6	2.5	7.5						
2.6	2.6	2.5	7.5						
2.6	2.6	2.5	7.5						
2.5	2.6	2.5	7.5						
2.4	2.8	2.5	7.5						
2.6	2.6	2.5	7.5						
2.5	2.8	2.5	7.5						
2.6	2.5	2.5	7.5						
2.5	2.5	2.6	17						
		2.6	17						
		2.6	17						
		2.6	17						
		2.6	17						
		2.6	17						
		2.6	17						
		2.6	17						
		2.6	17						
		2.6	17						
		2.6	17						
		2.6	17						
		2.6	17						
		2.8	23.5						
		2.8	23.5						

**Table C.11
Wilcoxon Rank Sum Tests (Metals Parameters in Surface Water)
Bar U Ranch National Historic Site, Alberta
Public Works and Government Services Canada**

Dissolved Sodium (Na)									
Dataset 1 (exposure)	Dataset 2 (background)	Combined and sorted	Rank (average)	W ⁽¹⁾	N1 ⁽²⁾	N2 ⁽³⁾	Z ⁽⁴⁾	Within background range?	Retain as a COC?
5.3	5.3	5.1	1.5	141.5	11	11	0.984975	Yes	No
5.4	5.3	5.1	1.5						
5.1	5.3	5.3	5.5						
5.3	5.5	5.3	5.5						
5.6	5.4	5.3	5.5						
5.5	5.4	5.3	5.5						
5.6	5.3	5.3	5.5						
5.6	5.1	5.3	5.5						
5.7	5.6	5.4	10.5						
5.5	5.5	5.4	10.5						
5.4	5.6	5.4	10.5						
		5.4	10.5						
		5.5	14.5						
		5.5	14.5						
		5.5	14.5						
		5.5	14.5						
		5.6	19						
		5.6	19						
		5.6	19						
		5.6	19						
		5.6	19						
		5.7	22						

Table C.11
Wilcoxon Rank Sum Tests (Metals Parameters in Surface Water)
Bar U Ranch National Historic Site, Alberta
Public Works and Government Services Canada

Dissolved Strontium									
Dataset 1 (exposure)	Dataset 2 (background)	Combined and sorted	Rank (average)	W ⁽¹⁾	N1 ⁽²⁾	N2 ⁽³⁾	Z ⁽⁴⁾	Within background range?	Retain as a COC?
0.37	0.36	0.3	2	129.5	12	12	-1.18357	Yes	No
0.32	0.32	0.3	2						
0.31	0.31	0.3	2						
0.31	0.32	0.31	7.5						
0.31	0.32	0.31	7.5						
0.32	0.32	0.31	7.5						
0.3	0.32	0.31	7.5						
0.3	0.35	0.31	7.5						
0.32	0.31	0.31	7.5						
0.31	0.35	0.31	7.5						
0.32	0.31	0.31	7.5						
0.31	0.3	0.32	16						
		0.32	16						
		0.32	16						
		0.32	16						
		0.32	16						
		0.32	16						
		0.32	16						
		0.32	16						
		0.32	16						
		0.32	16						
		0.35	21.5						
		0.35	21.5						
		0.36	23						
		0.37	24						

Table C.11

**Wilcoxon Rank Sum Tests (Metals Parameters in Surface Water)
Bar U Ranch National Historic Site, Alberta
Public Works and Government Services Canada**

Dissolved Sulphur									
Dataset 1 (exposure)	Dataset 2 (background)	Combined and sorted	Rank (average)	$W^{(1)}$	$N1^{(2)}$	$N2^{(3)}$	$Z^{(4)}$	Within background range?	Retain as a COC?
11	11	7.8	1	139	12	12	-0.63509	Yes	No
8.3	8.4	7.9	2						
8.1	8	8	4.5						
8.2	8.2	8	4.5						
8.3	8.4	8	4.5						
8.5	8.2	8	4.5						
8	8.3	8.1	8						
7.8	9.2	8.1	8						
8.2	7.9	8.1	8						
8.1	9.1	8.2	11.5						
8.3	8.1	8.2	11.5						
8	8	8.2	11.5						
		8.2	11.5						
		8.3	15.5						
		8.3	15.5						
		8.3	15.5						
		8.3	15.5						
		8.4	18.5						
		8.4	18.5						
		8.5	20						
		9.1	21						
		9.2	22						
		11	23.5						
		11	23.5						

Table C.11
Wilcoxon Rank Sum Tests (Metals Parameters in Surface Water)
Bar U Ranch National Historic Site, Alberta
Public Works and Government Services Canada

Notes:

Calculation equation is described by PWGSC (2011)

⁽¹⁾ W - sum of ranks of dataset 1

⁽²⁾ N1 - sample size of dataset 1 (includes all discrete data). 1/2 the reportable detection limits are used for non-detect values. If a field duplicate sample was available, only the higher of the original or the duplicate was used.

⁽³⁾ N2 - sample size of dataset 2 (background samples)

⁽⁴⁾ Z - Wilcoxon rank-sum test z statistic (if $z < -3$ or $z > 3$, the parameter concentrations are not considered related to background concentrations)

References:

Public Works and Government Services Canada (PWGSC), 2011. Environment Canada Background Soil Quality Data, Newfoundland and Labrador (NL) (2005-09) Revision 2. Technical Assistance Document No. 1 (PWGSC TAD No.1), March 2011

Prepared by: SP

Checked by: TR

Table C.12
Wilcoxon Rank Sum Tests - Summary in Surface Water
Bar U Ranch National Historic Site, Alberta
Public Works and Government Services Canada

Parameter	W ⁽¹⁾	N1 ⁽²⁾	N2 ⁽³⁾	Z ⁽⁴⁾	Within background range?	Retain as a COC?
Dissolved nitrate	156	12	12	0.35	Yes	No
Dissolved nitrate	148	12	12	-0.14	Yes	No
Metals						
Barium	127.5	12	12	-1.30	Yes	No
Chromium	153	12	12	0.17	Yes	No
Magnesium	161	12	12	0.64	Yes	No
Potassium	161	12	12	0.64	Yes	No
Silicon	127	12	12	-1.36	Yes	No
Sodium	141.5	11	11	0.98	Yes	No
Strontium	129.5	12.0	12.0	-1.18	Yes	No
Sulphur	139	12	12	-0.64	Yes	No

Notes:

COC - Contaminant of concern

⁽¹⁾ W - sum of ranks of dataset 1

⁽²⁾ N1 - sample size of dataset 1 (includes all discrete data). 1/2 the reportable detection limits are used for non-detect values. If a field duplicate sample was available, only the higher of the original or the duplicate was used.

⁽³⁾ N2 - sample size of dataset 2 (background samples)

⁽⁴⁾ Z - Wilcoxon rank-sum test z statistic (if $z < -3$ or $z > 3$, the parameter concentrations are not considered related to background concentrations)

Bold and shaded Z statistic is outside range between -3 and 3

References:

Public Works and Government Services Canada (PWGSC), 2011. Environment Canada Background Soil Quality Data, Newfoundland and Labrador (NL) (2005-09) Revision 2. Technical Assistance Document No. 1 (PWGSC TAD No.1), March 2011

Prepared by: SP

Checked by: TR

Table C.13
Tier 1 Screening - Metals in Sediment
Bar U Ranch National Historic Site, Alberta
Public Works and Government Services Canada

Parameter	Units	CCME Guidelines ISQGs ^(a)	CCME Guidelines PELs ^(b)	Selected Guideline	Maximum Measured Concentration	Location of Maximum Concentration	Retain as a COC?
Total Antimony (Sb)	mg/kg	ng	ng	ng	< 0.50	All locations	No
Total Arsenic (As)	mg/kg	5.9	17	5.9 ^(a)	7.5	SD16-08-01	Yes
Total Barium (Ba)	mg/kg	ng	ng	ng	260	SD16-06-01	Yes
Total Beryllium (Be)	mg/kg	ng	ng	ng	0.6	SD16-02-03	Yes
Soluble (Hot water) Boron (B)	mg/kg	ng	ng	ng	4.1	SD16-07-02	No (see text)
Total Cadmium (Cd)	mg/kg	0.6	3.5	0.6 ^(a)	0.57	SD16-07-01	No
Hex. Chromium (Cr 6+)	mg/kg	ng	ng	ng	< 0.080	All locations	No
Total Chromium (Cr)	mg/kg	37.3	90	37.3 ^(a)	31	SD16-08-01	No
Total Cobalt (Co)	mg/kg	ng	ng	ng	7.4	SD16-02-02	Yes
Total Copper (Cu)	mg/kg	35.7	197	35.7 ^(a)	29	SD16-06-01	No
Total Lead (Pb)	mg/kg	35	91.3	35 ^(a)	9.1	SD16-02-03, SD16-02-04	No
Total Mercury (Hg)	mg/kg	0.17	0.486	0.17 ^(a)	0.07	SD16-07-01	No
Total Molybdenum (Mo)	mg/kg	ng	ng	ng	1.6	SD16-02-02	Yes
Total Nickel (Ni)	mg/kg	ng	ng	ng	30	SD16-02-02	Yes
Total Selenium (Se)	mg/kg	ng	ng	ng	1.4	SD16-07-01	Yes
Total Silver (Ag)	mg/kg	ng	ng	ng	< 0.20	All locations	No
Total Thallium (Tl)	mg/kg	ng	ng	ng	0.15	SD16-07-01	Yes
Total Tin (Sn)	mg/kg	ng	ng	ng	< 1.0	All locations	No
Total Uranium (U)	mg/kg	ng	ng	ng	0.73	SD16-02-02	Yes
Total Vanadium (V)	mg/kg	ng	ng	ng	31	SD16-02-03	Yes
Total Zinc (Zn)	mg/kg	123	315	123 ^(a)	85	SD16-02-04	No

Notes:

(a) Canadian Council of Ministers of the Environment (CCME) Canadian Sediment Quality Guidelines for the Protection of Aquatic Life in Freshwater, Interim Sediment Quality Guidelines (ISQGs), current to 2018.

(b) Canadian Council of Ministers of the Environment (CCME) Canadian Sediment Quality Guidelines for the Protection of Aquatic Life in Freshwater, Probably Effect Levels (PELs). Presented for comparative purposes only.

mg/kg - milligrams per kilogram

ng - no guideline

COC - Contaminant of concern

< - less than reportable detection limit

BOLD indicates an exceedance of the selected guideline

Table should be read in conjunction with accompanying report.

Prepared by: HT/AB

Checked by: TR

Table C.14
Tier 1 Screening - Polycyclic Aromatic Hydrocarbons in Sediment
Bar U Ranch National Historic Site, Alberta
Public Works and Government Services Canada

Parameter	Units	CCME Guidelines ISQGs ^(a)	CCME Guidelines PELs ^(b)	Selected Guideline	Maximum Measured Concentration ^(c)	Location of Maximum Concentration	Retain as a COC?
Acenaphthene	mg/kg	0.00671	0.0889	0.00671 ^(a)	< 0.020	SD16-07-02	No ^(d)
Acenaphthylene	mg/kg	0.00587	0.128	0.00587 ^(a)	< 0.020	SD16-07-02	No
Acridine	mg/kg	ng	ng	ng	< 0.040	SD16-07-02	No ^(d)
Anthracene	mg/kg	0.0469	0.245	0.0469 ^(a)	< 0.016	SD16-07-02	No
Benzo(a)anthracene	mg/kg	0.0317	0.385	0.0317 ^(a)	< 0.020	SD16-07-02	No
Benzo(b&j)fluoranthene	mg/kg	ng	ng	ng	<0.02 (0.015)	SD16-08-02	Yes
Benzo(k)fluoranthene	mg/kg	ng	ng	ng	< 0.020	SD16-07-02	No ^(d)
Benzo(g,h,i)perylene	mg/kg	ng	ng	ng	<0.02 (0.019)	SD16-08-02	Yes
Benzo(c)phenanthrene	mg/kg	ng	ng	ng	< 0.020	SD16-07-02	No ^(d)
Benzo(a)pyrene	mg/kg	0.0319	0.782	0.0319 ^(a)	< 0.020	SD16-07-02	No
Benzo(e)pyrene	mg/kg	ng	ng	ng	0.026	SD16-08-02	Yes
Chrysene	mg/kg	0.0571	0.862	0.0571 ^(a)	<0.02 (0.014)	SD16-08-02	No
Dibenz(a,h)anthracene	mg/kg	0.00622	0.135	0.00622 ^(a)	< 0.020	SD16-07-02	No ^(d)
Fluoranthene	mg/kg	0.111	2.355	0.111 ^(a)	<0.02 (0.0078)	SD16-08-02	No
Fluorene	mg/kg	0.0212	0.144	0.0212 ^(a)	<0.02 (0.0075)	SD16-07-02	No
Indeno(1,2,3-cd)pyrene	mg/kg	ng	ng	ng	< 0.020	SD16-07-02	No ^(d)
2-Methylnaphthalene	mg/kg	0.0202	0.201	0.0202 ^(a)	0.062	SD16-07-02	Yes
Naphthalene	mg/kg	0.0346	0.391	0.0346 ^(a)	0.03	SD16-06-02	No
Phenanthrene	mg/kg	0.0419	0.515	0.0419 ^(a)	0.051	SD16-06-01, SD16-08-01	Yes
Perylene	mg/kg	ng	ng	ng	<0.02 (0.012)	SD16-06-01, SD16-06-02	Yes
Pyrene	mg/kg	0.0530	0.875	0.0530 ^(a)	<0.02 (0.017)	SD16-08-02	No
Quinoline	mg/kg	ng	ng	ng	< 0.040	SD16-07-02	No ^(d)

Notes:

(a) Canadian Council of Ministers of the Environment (CCME) Canadian Sediment Quality Guidelines for the Protection of Aquatic Life in Freshwater, Interim Sediment Quality Guidelines (ISQGs), current to 2018.

(b) Canadian Council of Ministers of the Environment (CCME) Canadian Sediment Quality Guidelines for the Protection of Aquatic Life in Freshwater, Probably Effect Levels (PELs). Presented for comparative purposes only.

(c) Maximum detectable concentration shown in brackets

(d) Concentrations from all samples were below the reporting detection limit; as such, the parameter was not retained as a COC.

mg/kg - milligrams per kilogram

ng - no guideline

COC - Contaminant of concern

< - less than reportable detection limit

BOLD indicates an exceedance of the selected guideline

Table should be read in conjunction with accompanying report.

Table C.15
Tier 1 Screening - Detailed Salinity Parameters in Sediment
Bar U Ranch National Historic Site, Alberta
Public Works and Government Services Canada

Parameter	Units	CCME Guidelines ISQGs ^(a)	CCME Guidelines PELs ^(b)	Selected Guideline	Maximum Measured Concentration	Location of Maximum Concentration	Retain as a COC?
Calculated Calcium (Ca)	mg/kg	ng	ng	ng	380	SD16-07-02	No (see text)
Calculated Magnesium (Mg)	mg/kg	ng	ng	ng	64	SD16-07-02	No (see text)
Calculated Sodium (Na)	mg/kg	ng	ng	ng	27	SD16-07-02	No (see text)
Calculated Potassium (K)	mg/kg	ng	ng	ng	19	SD16-07-01	No (see text)
Calculated Chloride (Cl)	mg/kg	ng	ng	ng	130	SD16-07-02	No (see text)
Calculated Sulphate (SO ₄)	mg/kg	ng	ng	ng	880	SD16-07-02	No (see text)
Soluble Chloride (Cl)	mg/L	ng	ng	ng	150	SD16-02-04	No (see text)
Soluble Conductivity	dS/m	ng	ng	ng	1.5	SD16-07-02	No ^(c)
Soluble (CaCl ₂) pH	pH	ng	ng	ng	6.87-7.71	SD16-08-01, SD16-02-04	No
Sodium Adsorption Ratio	N/A	ng	ng	ng	0.52	SD16-08-01	No ^(c)
Soluble Calcium (Ca)	mg/L	ng	ng	ng	310	SD16-07-02	No (see text)
Soluble Magnesium (Mg)	mg/L	ng	ng	ng	53	SD16-07-02	No (see text)
Soluble Nitrate (N)	mg/L	ng	ng	ng	22	SD16-07-02	Yes
Soluble Sodium (Na)	mg/L	ng	ng	ng	15	SD16-07-01	No (see text)
Soluble Potassium (K)	mg/L	ng	ng	ng	120	SD16-07-01	No (see text)
Soluble Sulphate (SO ₄)	mg/L	ng	ng	ng	730	SD16-07-02	No (see text)
Theoretical Gypsum Requirement	tonnes/ha	ng	ng	ng	< 0.20	All locations	No

Notes:

(a) Canadian Council of Ministers of the Environment (CCME) Canadian Sediment Quality Guidelines for the Protection of Aquatic Life in Freshwater, Interim Sediment Quality Guidelines (ISQGs), current to 2018.

(b) Canadian Council of Ministers of the Environment (CCME) Canadian Sediment Quality Guidelines for the Protection of Aquatic Life in Freshwater, Probably Effect Levels (PELs). Presented for comparative purposes only.

(c) Salinity parameter is indicative of sediment quality and is not considered a potential contaminant of concern

mg/kg - milligrams per kilogram

mg/L - milligram per litre

N/A - not available

dS/m - decisiemens per metre

tonnes/ha - tonnes per hectare

ng - no guideline

COC - Contaminant of concern

< - less than reportable detection limit

BOLD indicates an exceedance of the selected guideline

Table should be read in conjunction with accompanying report.

Prepared by: HT/AB

Checked by: TR

**Wilcoxon Rank Sum Tests (Metals in Sediment)
Bar U Ranch National Historic Site, Alberta
Public Works and Government Services Canada**

Total arsenic									
Dataset 1 (exposure)	Dataset 2 (background)	Combined and sorted	Rank (average)	W ⁽¹⁾	N1 ⁽²⁾	N2 ⁽³⁾	Z ⁽⁴⁾	Within background range?	Retain as a COC?
6.2	5.1	3	1	121.5	11	11	-0.32833	Yes	No
7.1	4.9	3.6	2						
7.4	4.9	3.7	3						
5.3	5	4.2	4.5						
4.2	6.5	4.2	4.5						
4.3	4.7	4.3	6						
3.7	4.7	4.7	7.5						
3.6	6.7	4.7	7.5						
3	4.2	4.9	9.5						
7.5	7.9	4.9	9.5						
7	6.3	5	11						
		5.1	12						
		5.3	13						
		6.2	14						
		6.3	15						
		6.5	16						
		6.7	17						
		7	18						
		7.1	19						
		7.4	20						
		7.5	21						
		7.9	22						

**Wilcoxon Rank Sum Tests (Metals in Sediment)
Bar U Ranch National Historic Site, Alberta
Public Works and Government Services Canada**

Total barium									
Dataset 1 (exposure)	Dataset 2 (background)	Combined and sorted	Rank (average)	W ⁽¹⁾	N1 ⁽²⁾	N2 ⁽³⁾	Z ⁽⁴⁾	Within background range?	Retain as a COC?
200	230	170	1	117	11	11	-0.62382	Yes	No
210	230	180	2.5						
210	230	180	2.5						
230	240	200	5.5						
260	200	200	5.5						
200	220	200	5.5						
230	240	200	5.5						
230	210	210	9						
220	250	210	9						
180	180	210	9						
200	170	220	11.5						
		220	11.5						
		230	15.5						
		230	15.5						
		230	15.5						
		230	15.5						
		230	15.5						
		230	15.5						
		240	19.5						
		240	19.5						
		250	21						
		260	22						

**Wilcoxon Rank Sum Tests (Metals in Sediment)
Bar U Ranch National Historic Site, Alberta
Public Works and Government Services Canada**

Total beryllium									
Dataset 1 (exposure)	Dataset 2 (background)	Combined and sorted	Rank (average)	W ⁽¹⁾	N1 ⁽²⁾	N2 ⁽³⁾	Z ⁽⁴⁾	Within background range?	Retain as a COC?
0.48	0.5	0.2	1	139.5	11	11	0.853645	Yes	No
0.57	0.48	0.45	2						
0.6	0.57	0.46	3						
0.55	0.51	0.47	4.5						
0.49	0.5	0.47	4.5						
0.2	0.47	0.48	6.5						
0.54	0.49	0.48	6.5						
0.53	0.47	0.49	8.5						
0.46	0.45	0.49	8.5						
0.51	0.56	0.5	10.5						
0.54	0.53	0.5	10.5						
		0.51	12.5						
		0.51	12.5						
		0.53	14.5						
		0.53	14.5						
		0.54	16.5						
		0.54	16.5						
		0.55	18						
		0.56	19						
		0.57	20.5						
		0.57	20.5						
		0.6	22						

**Wilcoxon Rank Sum Tests (Metals in Sediment)
Bar U Ranch National Historic Site, Alberta
Public Works and Government Services Canada**

Total cobalt									
Dataset 1 (exposure)	Dataset 2 (background)	Combined and sorted	Rank (average)	W ⁽¹⁾	N1 ⁽²⁾	N2 ⁽³⁾	Z ⁽⁴⁾	Within background range?	Retain as a COC?
6.8	6.3	5.3	1	125	11	11	-0.0985	Yes	No
7.4	6.3	5.7	2						
7.1	6.4	5.9	3						
7.1	6.5	6	4						
6	7.1	6.1	5						
5.9	6.3	6.3	7.5						
6.3	6.4	6.3	7.5						
5.3	6.6	6.3	7.5						
5.7	6.1	6.3	7.5						
7.1	8.1	6.4	10.5						
7	6.6	6.4	10.5						
		6.5	12						
		6.6	13.5						
		6.6	13.5						
		6.8	15						
		7	16						
		7.1	18.5						
		7.1	18.5						
		7.1	18.5						
		7.1	18.5						
		7.4	21						
		8.1	22						

**Wilcoxon Rank Sum Tests (Metals in Sediment)
Bar U Ranch National Historic Site, Alberta
Public Works and Government Services Canada**

Total molybdenum									
Dataset 1 (exposure)	Dataset 2 (background)	Combined and sorted	Rank (average)	W ⁽¹⁾	N1 ⁽²⁾	N2 ⁽³⁾	Z ⁽⁴⁾	Within background range?	Retain as a COC?
0.73	0.81	0.49	1	138	11	11	0.755	Yes	No
1.6	0.68	0.57	2						
1.3	0.61	0.58	3						
0.98	0.63	0.59	4						
0.65	0.8	0.61	5						
0.49	0.7	0.63	6						
0.57	0.59	0.65	7						
1	0.89	0.66	8						
0.58	0.66	0.68	9						
1.1	1	0.7	10						
0.84	0.73	0.73	11.5						
		0.73	11.5						
		0.8	13						
		0.81	14						
		0.84	15						
		0.89	16						
		0.98	17						
		1	18.5						
		1	18.5						
		1.1	20						
		1.3	21						
		1.6	22						

**Wilcoxon Rank Sum Tests (Metals in Sediment)
Bar U Ranch National Historic Site, Alberta
Public Works and Government Services Canada**

Total nickel									
Dataset 1 (exposure)	Dataset 2 (background)	Combined and sorted	Rank (average)	W ⁽¹⁾	N1 ⁽²⁾	N2 ⁽³⁾	Z ⁽⁴⁾	Within background range?	Retain as a COC?
23	23	19	1.5	129	11	11	0.164163	Yes	No
30	22	19	1.5						
29	20	20	4.5						
25	20	20	4.5						
20	24	20	4.5						
19	22	20	4.5						
21	20	21	8						
22	24	21	8						
19	24	21	8						
29	27	22	11						
21	21	22	11						
		22	11						
		23	13.5						
		23	13.5						
		24	16						
		24	16						
		24	16						
		25	18						
		27	19						
		29	20.5						
		29	20.5						
		30	22						

**Wilcoxon Rank Sum Tests (Metals in Sediment)
Bar U Ranch National Historic Site, Alberta
Public Works and Government Services Canada**

Total selenium									
Dataset 1 (exposure)	Dataset 2 (background)	Combined and sorted	Rank (average)	W ⁽¹⁾	N1 ⁽²⁾	N2 ⁽³⁾	Z ⁽⁴⁾	Within background range?	Retain as a COC?
0.25	0.56	0.25	3.5	142	11	11	1.02	Yes	No
0.7	0.6	0.25	3.5						
0.63	0.7	0.25	3.5						
0.62	0.62	0.25	3.5						
0.81	0.51	0.25	3.5						
0.56	0.61	0.25	3.5						
0.75	0.64	0.51	7						
1.4	0.25	0.56	8.5						
1.2	0.82	0.56	8.5						
0.25	0.25	0.6	10						
0.25	0.25	0.61	11						
		0.62	12.5						
		0.62	12.5						
		0.63	14						
		0.64	15						
		0.7	16.5						
		0.7	16.5						
		0.75	18						
		0.81	19						
		0.82	20						
		1.2	21						
		1.4	22						

**Wilcoxon Rank Sum Tests (Metals in Sediment)
Bar U Ranch National Historic Site, Alberta
Public Works and Government Services Canada**

Total thallium									
Dataset 1 (exposure)	Dataset 2 (background)	Combined and sorted	Rank (average)	W ⁽¹⁾	N1 ⁽²⁾	N2 ⁽³⁾	Z ⁽⁴⁾	Within background range?	Retain as a COC?
0.05	0.05	0.05	4.5	151.5	11	11	1.64	Yes	No
0.11	0.05	0.05	4.5						
0.05	0.11	0.05	4.5						
0.14	0.05	0.05	4.5						
0.11	0.1	0.05	4.5						
0.05	0.05	0.05	4.5						
0.12	0.1	0.05	4.5						
0.15	0.1	0.05	4.5						
0.12	0.1	0.1	11.5						
0.1	0.11	0.1	11.5						
0.1	0.05	0.1	11.5						
		0.1	11.5						
		0.1	11.5						
		0.1	11.5						
		0.11	16.5						
		0.11	16.5						
		0.11	16.5						
		0.11	16.5						
		0.12	19.5						
		0.12	19.5						
		0.14	21						
		0.15	22						

**Wilcoxon Rank Sum Tests (Metals in Sediment)
Bar U Ranch National Historic Site, Alberta
Public Works and Government Services Canada**

Total uranium									
Dataset 1 (exposure)	Dataset 2 (background)	Combined and sorted	Rank (average)	W ⁽¹⁾	N1 ⁽²⁾	N2 ⁽³⁾	Z ⁽⁴⁾	Within background range?	Retain as a COC?
0.52	0.48	0.41	1	153.5	11	11	1.772955	Yes	No
0.73	0.45	0.45	2						
0.63	0.46	0.46	3						
0.7	0.5	0.47	4.5						
0.51	0.52	0.47	4.5						
0.41	0.54	0.48	6						
0.51	0.47	0.5	7						
0.58	0.54	0.51	8.5						
0.64	0.47	0.51	8.5						
0.55	0.64	0.52	11						
0.52	0.54	0.52	11						
		0.52	11						
		0.54	14						
		0.54	14						
		0.54	14						
		0.55	16						
		0.58	17						
		0.63	18						
		0.64	19.5						
		0.64	19.5						
		0.7	21						
		0.73	22						

**Wilcoxon Rank Sum Tests (Metals in Sediment)
Bar U Ranch National Historic Site, Alberta
Public Works and Government Services Canada**

Total vanadium									
Dataset 1 (exposure)	Dataset 2 (background)	Combined and sorted	Rank (average)	W ⁽¹⁾	N1 ⁽²⁾	N2 ⁽³⁾	Z ⁽⁴⁾	Within background range?	Retain as a COC?
25	23	18	1.5	131.5	11	11	0.328325	Yes	No
29	22	18	1.5						
31	23	20	3						
28	24	21	4.5						
21	27	21	4.5						
18	24	22	6						
27	26	23	7.5						
18	27	23	7.5						
20	21	24	9.5						
29	32	24	9.5						
28	26	25	11						
		26	12.5						
		26	12.5						
		27	15						
		27	15						
		27	15						
		28	17.5						
		28	17.5						
		29	19.5						
		29	19.5						
		31	21						
		32	22						

**Wilcoxon Rank Sum Tests (Metals in Sediment)
Bar U Ranch National Historic Site, Alberta
Public Works and Government Services Canada**

Notes:

Calculation equation is described by PWGSC (2011)

⁽¹⁾ W - sum of ranks of dataset 1

⁽²⁾ N1 - sample size of dataset 1 (includes all discrete data). 1/2 the reportable detection limits are used for non-detect values. If a field duplicate sample was available, only the higher of the original or the duplicate was used.

⁽³⁾ N2 - sample size of dataset 2 (background samples)

⁽⁴⁾ Z - Wilcoxon rank-sum test z statistic (if $z < -3$ or $z > 3$, the parameter concentrations are not considered related to background concentrations)

References:

Public Works and Government Services Canada (PWGSC), 2011. Environment Canada Background Soil Quality Data, Newfoundland and Labrador (NL) (2005-09) Revision 2. Technical Assistance Document No. 1 (PWGSC TAD No.1), March 2011

Prepared by: SP

Checked by: TR

Table C.17
Wilcoxon Rank Sum Tests (Metals in Sediment)
Bar U Ranch National Historic Site, Alberta
Public Works and Government Services Canada

Benzo(b&j)fluoranthene									
Dataset 1 (exposure)	Dataset 2 (background)	Combined and sorted	Rank (average)	$W^{(1)}$	$N1^{(2)}$	$N2^{(3)}$	$Z^{(4)}$	Within background range?	Retain as a COC?
0.011	0.013	0.007	1	119	11	11	-0.49249	Yes	No
0.011	0.013	0.0076	2						
0.012	0.015	0.0079	3						
0.0076	0.012	0.0085	4						
0.014	0.016	0.01	5.5						
0.012	0.011	0.01	5.5						
0.012	0.012	0.011	8.5						
0.007	0.011	0.011	8.5						
0.01	0.0085	0.011	8.5						
0.012	0.0079	0.011	8.5						
0.015	0.01	0.012	13.5						
		0.012	13.5						
		0.012	13.5						
		0.012	13.5						
		0.012	13.5						
		0.012	13.5						
		0.013	17.5						
		0.013	17.5						
		0.014	19						
		0.015	20.5						
		0.015	20.5						
		0.016	22						

Table C.17
Wilcoxon Rank Sum Tests (Metals in Sediment)
Bar U Ranch National Historic Site, Alberta
Public Works and Government Services Canada

Benzo(g,h,i)perylene									
Dataset 1 (exposure)	Dataset 2 (background)	Combined and sorted	Rank (average)	W ⁽¹⁾	N1 ⁽²⁾	N2 ⁽³⁾	Z ⁽⁴⁾	Within background range?	Retain as a COC?
0.0025	0.005	0.0025	3	120.5	11	11	-0.39399	Yes	No
0.0082	0.0025	0.0025	3						
0.0091	0.006	0.0025	3						
0.0025	0.005	0.0025	3						
0.00475	0.013	0.0025	3						
0.005	0.0086	0.00475	6						
0.0025	0.0025	0.005	8						
0.007	0.013	0.005	8						
0.01	0.0085	0.005	8						
0.014	0.01	0.006	10						
0.019	0.012	0.007	11						
		0.0082	12						
		0.0085	13						
		0.0086	14						
		0.0091	15						
		0.01	16.5						
		0.01	16.5						
		0.012	18						
		0.013	19.5						
		0.013	19.5						
		0.014	21						
		0.019	22						

Table C.17
Wilcoxon Rank Sum Tests (Metals in Sediment)
Bar U Ranch National Historic Site, Alberta
Public Works and Government Services Canada

Benzo[e]pyrene									
Dataset 1 (exposure)	Dataset 2 (background)	Combined and sorted	Rank (average)	W ⁽¹⁾	N1 ⁽²⁾	N2 ⁽³⁾	Z ⁽⁴⁾	Within background range?	Retain as a COC?
0.014	0.017	0.007	1	120.5	11	11	-0.39399	Yes	No
0.014	0.016	0.0097	2						
0.015	0.021	0.01	3						
0.0097	0.016	0.014	5						
0.018	0.023	0.014	5						
0.017	0.016	0.014	5						
0.015	0.015	0.015	8						
0.007	0.019	0.015	8						
0.01	0.019	0.015	8						
0.02	0.014	0.016	11						
0.026	0.017	0.016	11						
		0.016	11						
		0.017	14						
		0.017	14						
		0.017	14						
		0.018	16						
		0.019	17.5						
		0.019	17.5						
		0.02	19						
		0.021	20						
		0.023	21						
		0.026	22						

Table C.17
Wilcoxon Rank Sum Tests (Metals in Sediment)
Bar U Ranch National Historic Site, Alberta
Public Works and Government Services Canada

2-methylnaphthalene									
Dataset 1 (exposure)	Dataset 2 (background)	Combined and sorted	Rank (average)	$W^{(1)}$	$N_1^{(2)}$	$N_2^{(3)}$	$Z^{(4)}$	Within background range?	Retain as a COC?
0.032	0.039	0.022	1.5	123.5	11	11	-0.197	Yes	No
0.024	0.037	0.022	1.5						
0.028	0.048	0.023	3						
0.022	0.039	0.024	4.5						
0.061	0.036	0.024	4.5						
0.053	0.033	0.026	6.5						
0.035	0.033	0.026	6.5						
0.046	0.024	0.028	8						
0.062	0.06	0.032	9						
0.023	0.026	0.033	10.5						
0.026	0.022	0.033	10.5						
		0.035	12						
		0.036	13						
		0.037	14						
		0.039	15.5						
		0.039	15.5						
		0.046	17						
		0.048	18						
		0.053	19						
		0.06	20						
		0.061	21						
		0.062	22						

**Table C.17
Wilcoxon Rank Sum Tests (Metals in Sediment)
Bar U Ranch National Historic Site, Alberta
Public Works and Government Services Canada**

Phenanthrene									
Dataset 1 (exposure)	Dataset 2 (background)	Combined and sorted	Rank (average)	W ⁽¹⁾	N1 ⁽²⁾	N2 ⁽³⁾	Z ⁽⁴⁾	Within background range?	Retain as a COC?
0.03	0.038	0.024	1	136	11	11	0.623818	Yes	No
0.029	0.041	0.025	2						
0.033	0.048	0.029	3.5						
0.024	0.036	0.029	3.5						
0.051	0.047	0.03	5						
0.042	0.032	0.032	6						
0.037	0.029	0.033	7						
0.04	0.035	0.034	8						
0.05	0.049	0.035	9						
0.051	0.025	0.036	10						
0.048	0.034	0.037	11						
		0.038	12						
		0.04	13						
		0.041	14						
		0.042	15						
		0.047	16						
		0.048	17.5						
		0.048	17.5						
		0.049	19						
		0.05	20						
		0.051	21.5						
		0.051	21.5						

Table C.17
Wilcoxon Rank Sum Tests (Metals in Sediment)
Bar U Ranch National Historic Site, Alberta
Public Works and Government Services Canada

Perylene									
Dataset 1 (exposure)	Dataset 2 (background)	Combined and sorted	Rank (average)	$W^{(1)}$	$N1^{(2)}$	$N2^{(3)}$	$Z^{(4)}$	Within background range?	Retain as a COC?
0.0096	0.011	0.0025	4	116.5	11	11	-0.65665	Yes	No
0.0079	0.0094	0.0025	4						
0.0025	0.017	0.0025	4						
0.0025	0.013	0.0025	4						
0.012	0.005	0.0025	4						
0.012	0.011	0.0025	4						
0.0025	0.0096	0.0025	4						
0.007	0.0025	0.005	8						
0.01	0.0085	0.007	9						
0.0025	0.0025	0.0079	10						
0.009	0.0025	0.0085	11						
		0.009	12						
		0.0094	13						
		0.0096	14.5						
		0.0096	14.5						
		0.01	16						
		0.011	17.5						
		0.011	17.5						
		0.012	19.5						
		0.012	19.5						
		0.013	21						
		0.017	22						

Table C.17
Wilcoxon Rank Sum Tests (Metals in Sediment)
Bar U Ranch National Historic Site, Alberta
Public Works and Government Services Canada

Notes:

Calculation equation is described by PWGSC (2011)

⁽¹⁾ W - sum of ranks of dataset 1

⁽²⁾ N1 - sample size of dataset 1 (includes all discrete data). 1/2 the reportable detection limits are used for non-detect values. If a field duplicate sample was available, only the higher of the original or the duplicate was used.

⁽³⁾ N2 - sample size of dataset 2 (background samples)

⁽⁴⁾ Z - Wilcoxon rank-sum test z statistic (if $z < -3$ or $z > 3$, the parameter concentrations are not considered related to background concentrations)

References:

Public Works and Government Services Canada (PWGSC), 2011. Environment Canada Background Soil Quality Data, Newfoundland and Labrador (NL) (2005-09) Revision 2. Technical Assistance Document No. 1 (PWGSC TAD No.1), March 2011

Prepared by: SP

Checked by: TR

Table C.18
Wilcoxon Rank Sum Tests (Metals in Sediment)
Bar U Ranch National Historic Site, Alberta
Public Works and Government Services Canada

Nitrate									
Dataset 1 (exposure)	Dataset 2 (background)	Combined and sorted	Rank (average)	W ⁽¹⁾	N1 ⁽²⁾	N2 ⁽³⁾	Z ⁽⁴⁾	Within background range?	Retain as a COC?
17	14	14	2.5	150.5	11	11	1.57596	Yes	No
18	14	14	2.5						
17	15	14	2.5						
18	14	14	2.5						
16	17	15	5.5						
18	19	15	5.5						
17	15	16	7						
21	19	17	10						
22	23	17	10						
20	14	17	10						
17	18	17	10						
		17	10						
		18	14.5						
		18	14.5						
		18	14.5						
		18	14.5						
		19	17.5						
		19	17.5						
		20	19						
		21	20						
		22	21						
		23	22						

Notes:

Calculation equation is described by PWGSC (2011)

⁽¹⁾ W - sum of ranks of dataset 1

⁽²⁾ N1 - sample size of dataset 1 (includes all discrete data). 1/2 the reportable detection limits are used for non-detect values. If a field duplicate sample was available, only the higher of the original or the duplicate was used.

⁽³⁾ N2 - sample size of dataset 2 (background samples)

⁽⁴⁾ Z - Wilcoxon rank-sum test z statistic (if z < -3 or z > 3, the parameter concentrations are not considered related to background concentrations)

References:

Public Works and Government Services Canada (PWGSC), 2011. Environment Canada Background Soil Quality Data, Newfoundland and Labrador (NL) (2005-09) Revision 2. Technical Assistance Document No. 1 (PWGSC TAD No.1), March 2011

Prepared by: SP

Checked by: TR

Table C.19
Wilcoxon Rank Sum Tests - Summary in Sediment
Bar U Ranch National Historic Site, Alberta
Public Works and Government Services Canada

Parameter	W ⁽¹⁾	N1 ⁽²⁾	N2 ⁽³⁾	Z ⁽⁴⁾	Within background range?	Retain as a COC?
Metals						
Arsenic	121.5	11	11	-0.33	Yes	No
Barium	117	11	11	-0.62	Yes	No
Beryllium	140	11	11	0.85	Yes	No
Cobalt	125	11	11	-0.10	Yes	No
Molybdenum	138	11	11	0.76	Yes	No
Nickel	129	11	11	0.16	Yes	No
Selenium	142	11	11	1.02	Yes	No
Thallium	152	11	11	1.64	Yes	No
Uranium	153.5	11	11	1.77	Yes	No
Vanadium	131.5	11.0	11.0	0.33	Yes	No
PAHs						
Benzo(b&j)fluoranthene	119	11	11	-0.49	Yes	No
Benzo(ghi)perylene	121	11	11	-0.39	Yes	No
Benzo[e]pyrene	121	11	11	-0.39	Yes	No
2-methylnaphthalene	124	11	11	-0.20	Yes	No
Phenanthrene	136	11	11	0.62	Yes	No
Perylene	116.5	11	11	-0.66	Yes	No
Salinity						
Nitrate	150.5	11	11	1.58	Yes	No

Notes:

COC - Contaminant of concern

⁽¹⁾ W - sum of ranks of dataset 1⁽²⁾ N1 - sample size of dataset 1 (includes all discrete data). 1/2 the reportable detection limits are used for non-detect values. If a field duplicate sample was available, only the higher of the original or the duplicate was used.⁽³⁾ N2 - sample size of dataset 2 (background samples)⁽⁴⁾ Z - Wilcoxon rank-sum test z statistic (if $z < -3$ or $z > 3$, the parameter concentrations are not considered related to background concentrations)

Bold and shaded Z statistic is outside range between -3 and 3

References:

Public Works and Government Services Canada (PWGSC), 2011. Environment Canada Background Soil Quality Data, Newfoundland and Labrador (NL) (2005-09) Revision 2. Technical Assistance Document No. 1 (PWGSC TAD No.1), March 2011

Prepared by: SP

Checked by: TR



APPENDIX D

Aquatic Habitat Assessment



FISH AND FISH HABITAT ASSESSMENT

Project Location

Pekisko Creek is a tributary of the Highwood River, within the Bow River watershed. Both spring and fall spawners are known to be present in Pekisko Creek. The habitat assessment of Pekisko Creek was conducted over a 700 meter reach in the vicinity of the Bar U National Historic site.

Table 1: Upstream and Downstream Coordinates of the Assessed 700m Reach

Location	UTM Coordinates (NAD 83, Zone 11U)	
	Easting	Nothing
Upstream End	695630	5589257
Downstream End	659763	5589621

Methods

The fish habitat assessment was based on a review of existing fish and fish habitat information and on the results of a field survey conducted on October 21, 2016 on Pekisko Creek in the vicinity of Bar U Ranch National Historic site.

Existing Fish and Fish Habitat Information

Existing information was obtained from Alberta Environment and Parks (AEP) Fish and Wildlife Management Information System (FWMIS) accessed on February 13, 2017, to determine fish species previously documented as being present in Pekisko Creek within the study area.

The identified fish species at the location were then checked to determine their status under the Committee on the Status of Endangered Wildlife in Canada (COSEWIC 2016), the species at Risk Act (SARA) (Government of Canada 2016) or the species at Risk program in Alberta (AEP 2016b).

Fish Habitat Assessment

Habitat Data Collection

During the assessment, habitat data was collected for a 700 m reach of Pekisko Creek. The surveyed reach was separated into distinct habitat units throughout the assessed reach (i.e., run, riffle, pool). The maximum depth, wetted and bankfull width was measured for each habitat unit. Habitat features for each habitat unit, including point velocity measurements, barriers to fish passage, bank stability, substrate, and the type of instream and overhead cover available were noted. Potential spawning habitat was also noted if present in the surveyed reach.

Stream Discharge Measurement

Discharge information was obtained from Alberta Environment and Parks (AEP) Alberta River Basins.

At habitat transects, point depth and velocities were measured corresponding distances at $\frac{1}{4}$, $\frac{1}{2}$ and $\frac{3}{4}$ of the wetted stream width at representative habitat unit types.



Field Water Quality Measurements

In-situ water quality measurements were taken with a calibrated YSI 556 meter. Water quality parameters measured included pH, temperature ($^{\circ}\text{C}$), specific conductivity ($\mu\text{s}/\text{cm}$) and dissolved oxygen (mg/L).

Results

Existing Fish and Fish Habitat Information

No fish sampling occurred at the time of survey, existing fish information for Pekisko Creek was obtained by desk top review of the FWMIS database (AEP2016a). FWMIS indicates the presence of two forage fish and six salmonid species. The two forage fish identified are emerald shiner (*Notropis atherinoides*) and longnose dace (*Rhinichthys cataractae*). The six salmonid species listed were brook trout (*Salvelinus fontinalis*), bull trout (*Salvelinus confluentus*), rainbow trout (*Oncorhynchus mykiss*), westslope Cutthroat Trout (*Oncorhynchus clarki*) and Cutbow (cutthroat trout and rainbow trout hybrids) (*Oncorhynchus clarki x mykiss*) and mountain whitefish (*Prosopium williamsoni*).

COSEWIC (COSEWIC 2016) list westslope cutthroat trout as “Threatened” in Alberta. Under SARA (Government of Canada 2016) westslope cutthroat trout are listed as Schedule 1, Threatened. Westslope cutthroat trout are listed as “Threatened” under the Species at Risk program in Alberta (AEP 2016a). Bull trout are considered a species of concern by Alberta and COSEWIC as a species of special concern under consideration for listed as threatened.

Fish Habitat Assessment

The habitat assessed within Pekisko Creek was alternating riffle and run (R3) and one deep pool. The wetted width ranges from 6 m to 18.5 m wide and the bankfull width ranging between 13 m to 34 m wide. The maximum measured depth was 0.40 m, 0.65 m and 1.5 m within riffle, R3 and P1 habitat types, respectively. Pekisko Creek has abundant unstable banks along the left downstream bank due to erosion of banks caused by high water flow. Instream cover within the watercourse was provided by large woody debris, substrate and turbulence. Overhead cover was provided by isolated areas of undercut banks. The substrate consisted of cobble, gravel and boulder in the riffle, run habitat and clay and silt in the pool habitat. There are exposed gravel bars throughout the study area. There is a 1.0 m high beaver dam extending across the channel at the upstream boundary of the surveyed area which may impede fish migration at the time of study.

The stream discharge was $0.5\text{m}^3/\text{sec.}$, information obtained from Alberta Environment and Parks (AEP) Alberta River Basins. The field water quality measurements were: water temperature of 2.55°C mid depth dissolved oxygen of $11.79\text{ mg}/\text{L}$, pH of 7.55 and specific conductivity of $242\ \mu\text{S}/\text{cm}$. Based on the measurements and above observations, the aquatic habitat was considered to be in good quality.

Fish Habitat Utilization

Westslope Cutthroat Trout, Bull Trout prefer river and streams with abundant cover such as undercut banks, pool-riffle habitat and riparian habitat. Habitat conditions in the surveyed area provide potential spawning habitat for salmonids. Bull trout, brook trout spawn in the fall within clean gravel and cobble substrate with higher velocity in riffle habitat. No redds were observed in the study area. Mountain whitefish are broadcast spawners over clean gravel and cobble and higher velocities within riffle areas. Habitat conditions observed in the study area ideal to support all life stages of salmonids known to be in Pekisko Creek.



Rainbow trout, cutbows have similar habitat requirements to bull trout and brook trout and are found in overlapping ranges.

Description of Aquatic Environment

Pekisko Creek is a Class C watercourse tributary of the Highwood River within the Bow River watershed. Pekisko Creek is known to contain westslope Cutthroat, Cutthroat hybrids with rainbow trout, rainbow trout, bull trout, brook trout, and mountain whitefish are also known to occur in Pekisko Creek.

https://golderassociates.sharepoint.com/sites/23181g/deliverables/ra_report/final_report/app_d - aquatic_habitat_assessment/app_d_fish_assessment.docx



APPENDIX E

SAR Assessment

DATE March 20, 2017

PROJECT No. 1663824

TO Tessa Roselli
Golder Associates

FROM Fergus Nicoll

EMAIL Fergus_Nicoll@golder.com

**RESULTS OF A HABITAT ASSESSMENT AND SPECIES AT RISK SCREENING
FOR THE BAR U RANCH NATIONAL HISTORIC SITE, ALBERTA**

Introduction

The following summarizes the results of a habitat assessment and Species at Risk (SAR) screening performed in at the BAR U Ranch National Historic Site, near Longview, Alberta. The Study Area focuses on the immediate vicinity of the former waste disposal middens, as well as nearby Pekisko Creek.

Background

Species at Risk Act (SARA)

At the federal level, Species at Risk (SAR) designations for species occurring in Canada are initially determined by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC). If approved by the federal Minister of the Environment, species are added to the federal List of Wildlife Species at Risk (Canada, 2002). Species that are included on Schedule 1 as endangered or threatened are afforded protection of critical habitat on federal lands under the *Species at Risk Act* (SARA) (Canada, 2002). On private or provincially-owned lands, only aquatic species and migratory birds listed as endangered, threatened or extirpated are protected under SARA, unless ordered by the Governor in Council.

Methods

A desktop screening was conducted for species listed in the SARA and/or assessed by COSEWIC that may occur in the Study Area. The results of this assessment are based on available desktop information, as well as review of imagery and Site photos, and an aquatics-only habitat assessment conducted by Golder staff. In order to confirm the presence/absence of SAR, SAR habitat, and/or significant natural features, additional surveys during the appropriate seasons would be required.

Sources reviewed include:

- Various documents and information available within the Species at Risk Public Registry, including recovery strategies and COSEWIC Status Reports (EC 2016);
- Various documents, information, and tools available from Alberta Environment and Parks, including the FWMIS database (AEP 2016)



- Bat Conservation International (BCI) range maps (BCI 2017);
- eBird database and mapping tools (eBird 2012);
- Existing Golder data for the Site and Vicinity, including results of a 2016 aquatic habitat assessment;
- Emails and other information from Parks Canada Agency Staff;
- Google Maps (Google 2017); and,
- Existing aerial imagery, mapping, and Site photographs.

An assessment was conducted to determine which SAR have the potential to be located in the Study Area. The potential for SAR to occur within the Study Area was assessed based on species range information, known records, interpretation of aerial imagery and site photos, historic land use practices, and the preferred habitat requirements of these species (Table 1). Species with ranges overlapping the Study Area, or recent occurrence records in the vicinity, were screened by comparing their habitat requirements to apparent habitat conditions on the Site.

The potential for the species to occur was determined through a probability of occurrence methodology. A ranking of Low indicates no suitable habitat availability for that species in the Study Area and no specimens identified. Moderate probability indicates greater potential for the species to occur, as suitable habitat appeared to be present in the Study Area, but no occurrence of the species recorded. High potential indicates a known species record in the Study Area (including identifications made during field surveys or during background data review) and good quality habitat is present. If a category could not be clearly determined based on the definitions above, professional opinion was used to make an assessment. Species screened as having a moderate to high potential to occur are considered to have suitable habitat conditions present and may require further confirmation to determine their status on the Site.

Habitat and Health Assessment

The Study Area includes the immediate vicinity of two former waste disposal middens as well as the nearby waters of the Pekisko Creek. The middens have been capped and are now covered in grassland. The surrounding area is primarily agricultural and open grassy areas, with some buildings associated with the Bar U Ranch. Pekisko Creek is a moderately flowing stream, with a variety of riffles, runs and pools. Cover occurs in the form of undercut banks and instream cover such as large woody debris. Substrate is a mix of cobble, gravel, boulder, and clay and silt. The riparian zone of this stream, includes woody vegetation such as trees.

Species at Risk

Only those species assessed as having a moderate or high likelihood to occur are included in this memorandum. Refer Table 1 for details on the status, likelihood and habitat use of these species.

Through the SAR screening, nine (9) SAR designated under the SARA, were identified as having a moderate or high likelihood to occur in the Study Area. Monarch (*Danaus plexippus*), northern leopard frog (*Lithobates pipiens*), Baird's sparrow (*Ammodramus bairdii*), peregrine falcon (*Falco peregrinus*), and short-eared owl (*Asio flammeus*), are designated as special concern under the SARA. Common nighthawk (*Chordeiles minor*), ferruginous hawk (*Buteo regalis*), and west slope cutthroat trout (*Oncorhynchus clarkii lewisi*), are designated as special concern under the SARA. Little brown myotis (*Myotis lucifugus*) is designated as endangered under SARA.

Three (3) additional species that have been assessed as SAR by COSEWIC, but are not yet designated under the SARA have a moderate or high likelihood to occur in the Study Area. Grizzly bear (*Ursus arctos*) was assessed as special concern by COSEWIC. Barn swallow (*Hirundo rustica*), bank swallow (*Riparia riparia*), and bull trout (*Salvelinus confluentus*) were assessed as threatened by COSEWIC.

Limitations

The outcomes of the SAR screening are based on information available to Golder at the time of the review and the status of species listed in the noted Acts and Regulations effective as of the date of this technical memo. Field investigations by a qualified biologist were limited to an aquatic habitat assessment. The review may be subject to limitations associated with base mapping and other information reviewed. It is advised that this screening be re-evaluated should changes in site conditions or legislation occur. In order to accurately and completely assess the Study Area for SAR, and other significant natural features, targeted field surveys during appropriate timing windows would be required.

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Table 1: Species at Risk

Common Name	Scientific Name	SARA (Sch 1) ¹	COSEWIC ²	Habitat Requirements	Potential to Occur on Site (Desktop)
Monarch	<i>Danaus plexippus</i>	Special Concern	Special Concern	This butterfly species is found wherever there are milkweed (<i>Asclepius</i> spp.) plants for its caterpillars, and wildflowers that supply a nectar source for adults; often found on abandoned farmland, meadows, open wetlands, prairies and roadsides, but also in city gardens and parks.	Moderate – could occur anywhere in the Study Area.
Northern leopard frog (western boreal/prairie populations)	<i>Lithobates pipiens</i>	Special Concern	Special Concern	Breeds in small bodies of water such as ponds, marshes, shallow portions of lakes, slow moving streams etc. In the summer it utilizes a variety of upland habitats, such as moist meadows and prairie for foraging.	Moderate – could occur anywhere in the Study Area.
Baird's sparrow	<i>Ammodramus bairdii</i>	Special Concern	Special Concern	This sparrow species nests in grasslands, including prairie, and anthropogenic grasslands that mimic native prairie (e.g. graminoid hayfields.)	Moderate – could nest in the grassland in the Study Area.
Barn swallow	<i>Hirundo rustica</i>	No Status	Threatened	Barn swallow breeds in areas that contain a suitable nesting structure, open areas for foraging, and usually a body of water or other source of mud. This species nests in human made structures including barns, buildings, sheds, bridges, and culverts. Preferred foraging habitat includes meadows, pastures, agricultural cropland, lake and river shorelines, cleared rights-of-way, and wetlands. Mud nests are fastened to vertical walls or built on a ledge underneath an overhang. Suitable nests from previous years are reused.	High – no nesting habitat in the actual study area, but it is known to nest nearby. It likely forages in the airspace above the Study Area.

Common Name	Scientific Name	SARA (Sch 1) ¹	COSEWIC ²	Habitat Requirements	Potential to Occur on Site (Desktop)
Bank swallow	<i>Riparia riparia</i>	No Status	Threatened	The bank swallow breeds in a variety of natural and anthropogenic habitats, including lake bluffs, stream and river banks, sand and gravel pits, and roadcuts. Nests are generally built in a vertical or near-vertical bank. Breeding sites are typically located near open foraging sites such as rivers, lakes, grasslands, agricultural fields, wetlands and riparian woods. Forested areas are generally avoided.	Moderate – the river banks in the Study Area, are likely to small for this species to nest. However it may nest nearby and forage in the airspace over the Study Area.
Common nighthawk	<i>Chordeiles minor</i>	Threatened	Threatened	These aerial foragers require areas with large open habitat where they nest on the ground. This includes farmland, open woodlands, clear-cuts, burns, rock outcrops, alvars, bog ferns, prairies, gravel pits, gravel rooftops in cities etc.	Moderate – could nest on the open areas of the Study Area, or forage in the airspace above.
Ferruginous hawk	<i>Buteo regalis</i>	Threatened	Threatened	The ferruginous hawk uses prairies and other open arid habitats dominated by grasses and sagebrush. It tends to avoid areas of extensive cultivation. It nests on trees or structures, where it can observe the surrounding landscape for prey. It is often associated with its favorite prey, Richardson's ground squirrel.	Moderate – could nest in the vicinity of the Study Area, and potentially forage in the grasslands of the Study Area.
Peregrine falcon	<i>Falco peregrinus</i>	Special Concern	Special Concern	The peregrine falcon nests in both natural locations containing cliff faces and also anthropogenic landscapes including urban centres containing tall buildings, open pit mines and quarries, and road cuts. Peregrine falcons nest on cliff ledges and crevices and building ledges. Nests consist of a simple scrape in the substrate. They feed over various open and forested habitats.	Moderate – no nesting habitat in the Study Area, but could feed over the open areas.

Common Name	Scientific Name	SARA (Sch 1) ¹	COSEWIC ²	Habitat Requirements	Potential to Occur on Site (Desktop)
Short-eared owl	<i>Asio flammeus</i>	Special Concern	Special Concern	The short-eared owl breeds in a variety of open habitats including grasslands, tundra, bogs, marshes, clearcuts, burns, airports, pastures and occasionally row crop agricultural fields. The primary factor in determining breeding habitat is proximity to small mammal prey resources. Nests are built on the ground at a dry site and usually adjacent to a clump of tall vegetation used for cover and concealment.	Moderate – could nest and forage in the open areas of the Study Area.
Grizzly bear (western population)	<i>Ursus arctos</i>	No Status	Special Concern	This bear species is a habitat generalist. Habitat use is dependent upon food availability, and most habitat types can be utilized.	High – has been seen in the vicinity of the Study Area by park staff, could occur anywhere.
Little brown myotis	<i>Myotis lucifugus</i>	Endangered	Endangered	This bat species will roost in both natural and man-made structures. This includes cavity trees as well as a variety of buildings. Caves or abandoned mines may be used for hibernaculum, but high humidity and stable above freezing temperatures are required. Forages over open areas, including water bodies of various types and sizes.	Moderate – although there is no maternity roosting habitat in the Study Area, trees and buildings in the vicinity are suitable. This species could forage in the airspace over the Study Area.
Bull trout (Nelson Rivers populations)	<i>Salvelinus confluentus</i>	No Status	Threatened	This species is a coldwater fish, found in lakes, streams and rivers. It utilizes cold, clean water bodies.	High – known to occur in Pekisko Creek.
West slope cutthroat trout	<i>Oncorhynchus clarkii lewisi</i>	Threatened	Threatened	This species is found in a variety of habitats. It prefers cold, clean water with flow, and various forms of cover.	High – known to occur in Pekisko Creek.

References

- Alberta Environment and Parks (AEP) 2016. URL : <http://aep.alberta.ca/fish-wildlife/species-at-risk/default.aspx>
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APPENDIX F

TRAV SCT

FCSAP TRAV SPREADSHEET						
HHRA Sheet						
Site Name: Bar U Ranch National Historic Site near Longview, Alberta FCS#: West Midden (Site 56488004) and East Midden (Site 56488005) DFRP #: 56498 Completed By: Golder Associates Ltd. (TR/JW/MZ) Date Completed: 16/02/2018 Document #: 10						
Question ¹		Response	Rationale/Evidence (document any assumptions, reports, or site-specific information; provide references)	Guidance ¹	Instructions	Flag (for review)
1. Pre-Screening						
A	Were all maximum measured COC concentrations below human health check values prior to conducting the RA?	n	Soil related COCs were still considered valid based on the Meridian HHRA, these will ultimately be risk managed with the recommendation of improving the middens caps.	If maximum chemical concentrations are all below the appropriate human health-based guidelines, then a HHRA is not required (provided that the assumptions that were used to derive the guidelines are valid). If no human health-based guidelines are available, then TRAV should be completed.	Complete HHRA and HHRA_COE tabs.	
B	Was the HHRA qualitative?	y	The HHRA was qualitative as the COCs retained for soil were based on the Meridian HHRA. No COCs were retained for evaluation in the HHRA in groundwater, surface water, or sediment based on the current investigation.	Provide rationale for conducting a qualitative HHRA (e.g., all human health related exposure pathways were eliminated). Most of the HHRA questions will not need to be completed if the HHRA was qualitative. An example of a qualitative HHRA would be one where all human health-related exposure pathways are ruled out based on site conditions.	If qualitative, provide rationale.	
i	Were there unacceptable risks associated with qualitative HHRA?	y	Unacceptable risks were identified based on soil COCs, for which risk management measures will be provided.	Describe the nature of the unacceptable risks in the rationale box. The information will be included in the summary and the remainder of the TRAV HHRA questions will not have to be answered.	If yes, then a major deficiency is assigned unless rationale is provided.	●
C	Was the HHRA conducted pre-remediation?					
D	Has Expert Support reviewed the HHRA?			Note that TRAV may still be completed even if Expert Support has reviewed the RA.		
i	Please provide Expert Support author(s), department(s), date(s) and title(s)					
ii	Were Expert Support comments incorporated or considered in the HHRA? If no, provide rationale.					
E	Did the risk assessor identify any major limitations with respect to the site characterization data, given the nature of the data and the hypothesis on contaminant distribution such that it might limit the conclusions of the HHRA?					
i	Did the risk assessor address the potential limitations of the site characterization data in the conclusions of the risk assessment?					
F	What land use was the HHRA based on?					
G	Describe any site use restrictions based on assumptions made in the risk assessment.			Indicate any site use restrictions (e.g., no buildings on site, etc.).		
2. Problem Formulation						
Objectives						
A	Are the study objectives clearly stated?			The purpose of the HHRA should be clear (e.g., why is the risk assessment being conducted?). The scope and complexity of the HHRA should be commensurate with the overall purpose of the risk assessment.		
i	Is it clear how the HHRA was used to support the study objectives?					
ii	Provide report reference where HHRA objectives are stated.					

FCSAP TRAV SPREADSHEET						
HHRA Sheet						
Site Name: Bar U Ranch National Historic Site near Longview, Alberta FCS#: West Midden (Site 56488004) and East Midden (Site 56488005) DFRP #: 56498 Completed By: Golder Associates Ltd. (TR/JW/MZ) Date Completed: 16/02/2018 Document #: 10						
Question ¹		Response	Rationale/Evidence (document any assumptions, reports, or site-specific information; provide references)	Guidance ¹	Instructions	Flag (for review)
Receptors, Pathways and CSM						
B	Which of the following relevant receptor groups were identified:					
i	General public or residents					
ii	Employees					
iii	Members of Aboriginal communities					
iv	Other					
C	Which of the following relevant receptor age groups were identified:					
i	Infant (0-6 mo.)					
ii	Toddler (7 mo.-4 yr)					
iii	Child (5-11 yr)					
iv	Teen (12-19 yr)					
v	Adult (≥ 20 yr)					
vi	Other					
D	Have potentially sensitive receptor population groups been identified?			e.g., children, the elderly, women of child-bearing age/pregnant women, Aboriginal communities		
E	Which of the following relevant direct and indirect exposure pathways were considered:			Indirect exposure pathways consider contaminant release mechanisms (e.g., volatilization, fugitive dust emission, surface runoff/overland flow, leaching to groundwater, tracking by human/animals, etc.) and contaminant transport mechanisms (e.g., diffusion, advection, biomagnifications, biodecay).		
i	Inadvertent ingestion of soil					
ii	Inhalation of soil particles					
iii	Inhalation of indoor contaminant vapours					
iv	Inhalation of outdoor contaminant vapours					
v	Ingestion of drinking water					
vi	Ingestion of contaminated food					
vii	Inadvertent ingestion of surface water					
viii	Inadvertent ingestion of sediment					
ix	Dermal contact with soil					
x	Dermal contact with groundwater					
xi	Dermal contact with surface water					
xii	Dermal contact with sediment					
xiii	Other					
F	Was a robust CSM developed that incorporates all elements of the problem formulation?			The CSM should illustrate the linkages between COCs, ROCs and exposure pathways and also consider the potential fate and transport of contaminants. Where exposure pathways are excluded, a rationale should be provided in the HHRA. The complexity of the CSM should be in keeping with the level of complexity of the HHRA.		

FCSAP TRAV SPREADSHEET						
HHRA Sheet						
Site Name: Bar U Ranch National Historic Site near Longview, Alberta FCS#: West Midden (Site 56488004) and East Midden (Site 56488005) DFRP #: 56498 Completed By: Golder Associates Ltd. (TR/JW/MZ) Date Completed: 16/02/2018 Document #: 10						
Question ¹	Response	Rationale/Evidence (document any assumptions, reports, or site-specific information; provide references)	Guidance ¹	Instructions	Flag (for review)	
3. Exposure Assessment						
A	For each complete exposure pathway/COC combination identified in the CSM were exposure point concentrations accounted for either using measured data or estimated data (simulated, predicted or modeled)?					
B	Was a model and/or equations used to predict environmental concentrations?		Environmental fate models or equations may be used to estimate or predict the concentration in one medium based on measured concentrations in another medium (e.g., estimating groundwater concentrations from soil concentrations, predicting indoor air concentrations from soil or groundwater concentrations, predicting a concentration in food based on soil concentrations).			
i	If a model or equations were used to predict environmental concentrations, was their use appropriate, were all input parameters justified, were assumptions explained and were references provided?		All model assumptions should be fully documented and equations with units provided. Intermediate calculations (e.g. concentrations at specific locations) should be presented so that, even if the calculations are not readily reproduced by hand, the sensibility of the calculations may be evaluated.			
ii	Have model predicted values been calibrated to or compared against measurement data from the site? Where applicable, has a mass balance check been performed? Do the comparisons of model predictions make sense?					
C	Were statistical analyses performed to calculate exposure concentrations?					
i	Are statistics used for exposure concentrations defensible given the sample size and the HHRA objectives?		Health Canada recommends the use of the arithmetic mean or upper 95% confidence interval of the mean depending on the quality and quantity of data available. Where data are limited, Health Canada prefers the use of the maximum measured concentration or 95th percentile of the data distribution.			
ii	Do the statistical analyses consider microenvironments separately?		Analysis of microenvironments can identify areas where unacceptable exposures could occur that would be missed entirely using data-averaging techniques to describe the site as a whole.			
D	Were all receptor exposure characteristics drawn from Health Canada guidance?		Health Canada guidance on receptor characteristics can be found in Part I of the guidance for Federal Contaminated Site Risk Assessment in Canada.			
i	Was an alternative source documented, were assumptions stated and justified?					
ii	Were assumptions related to exposure duration and frequency appropriate?		Health Canada provides exposure frequency and duration data specified by land use. The Compendium of Canadian Human Exposure Factors for Risk Assessment (Richardson and O'Connor Assoc., 1997) also provides Canadian data. Another source of data is the US EPA Exposure Factors Manuals (US EPA 1997, 2002). Site specific data can also be gathered.			
E	Were Health Canada exposure equations used?		Exposure equations can be found in Part I of the guidance for Federal Contaminated Site Risk Assessment in Canada.			
i	If not is there adequate rationale for using alternatives?					
F	Was bioavailability other than 100% used in the HHRA for the oral or inhalation pathways?		Refer to Health Canada PQRA and DQRA guidance for incorporating bioavailability into the HHRA.			
i	Is the use of bioavailability other than 100% supported by testing or literature and is the source of the value fully explained and referenced?		Absorption factors for ingestion and inhalation are usually assumed to be 100%. The use of oral or inhalation bioavailability factors less than 100% must be fully explained and referenced.			
ii	Has consideration been given to relative versus absolute bioavailability?		When adjusting exposure assessment calculations for the bioavailability of a contaminant in soil, this must be done relative to the gastrointestinal absorption of the same substance in the toxicological or epidemiological study upon which the TRV is based.			
G	If the dermal pathway is operable, are HC relative absorption factors used or were the values based on scientific literature and defensible?		Dermal absorption factors are provided in Health Canada guidance. For chemicals not listed by Health Canada, alternative sources should be referenced.			
H	Were any exposure durations considered subchronic or acute?		For the purposes of exposure assessment, three different lengths of exposure are used in the classification of exposure duration for human receptors: • acute (assumed to be less than 14 days, but often involving a single high-intensity exposure) • subchronic (assumed to be greater than 14 days and less than 90 days) • chronic (greater than 90 days) See Health Canada guidance regarding acute, subchronic and chronic exposures.			
i	If yes, have subchronic and/or acute exposures been properly amortized?					

FCSAP TRAV SPREADSHEET						
HHRA Sheet						
Site Name: Bar U Ranch National Historic Site near Longview, Alberta FCS# : West Midden (Site 56488004) and East Midden (Site 56488005) DFRP #: 56498 Completed By: Golder Associates Ltd. (TR/JW/MZ) Date Completed: 16/02/2018 Document #: 10						
Question ¹	Response	Rationale/Evidence (document any assumptions, reports, or site-specific information; provide references)	Guidance ¹	Instructions	Flag (for review)	
I	Are any COCs developmental toxicants?		Examples of developmental toxicants include but are not limited to: bis (2-ethyl-hexyl)phthalate, dibutyl phthalate, ethylbenzene, methylmercury, molybdenum, polychlorinated dibenzo-p-dioxins and dibenzofurans (PCDD/DF), trichloroethylene and xylenes.			
i	If yes, have exposures been properly amortized?		The possibility of developmental toxicity will influence the appropriateness of exposure amortization procedures.			
J	Were Health Canada's recommended procedures to account for different cancer risks based on life stage of exposure followed?		e.g., has weighted-average exposure based on the duration of each life stage been considered when assessing cancer risks? See Health Canada guidance for additional details.			
K	Was a probabilistic RA conducted?					
i	Have the input parameters and associated probability distributions been justified?		Refer to Health Canada DQRA guidance for information regarding probabilistic risk assessments.			
4. Toxicity Assessment						
A	Are the selected TRVs clearly stated, with references for each chemical and pathway combination?					
B	Were only HC TRV values used?		Health Canada TRVs are provided in Part II of their guidance on conducting Human Health Risk Assessments.			
i	If HC TRV values were not used, are TRVs defensible and justified?		Health Canada provides an order of preference for selecting TRVs from other agencies: 1: US EPA; 2: WHO; 3: RIVM; 4: ATSDR			
C	Are the health effects associated with each COC and the basis for the TRV described?					
D	Are any TRV values extrapolated from an oral to an inhalation route?		If an inhalation-specific TRV is not available, then as long as it is reasonable to assume that the toxic mode of action and target organ(s) would be similar for the different exposure routes, the exposures from multiple exposure routes should be combined for comparison to the oral TRV. This extrapolation requires an assessment of the relative bioavailability from the exposure routes in question.			
i	If yes, has bioavailability between exposure routes been considered?					
E	Have any TRVs been developed <i>de novo</i> ?		Health Canada allows <i>de novo</i> derivation of TRVs (particularly important for chemicals that have no regulatory agency-derived TRV). Nevertheless, <i>de novo</i> TRV derivation requires extensive documentation of the rationale supporting the TRV.			
i	Was Health Canada guidance with respect to <i>de novo</i> TRVs followed?		Health Canada has detailed guidance with respect to developing <i>de novo</i> TRVs, which should be followed. This guidance is called "Guidance for the Development of Toxicity Reference Values (TRVs) for Federal Contaminated Site Risk Assessments, In the Absence of Published Regulatory TRVs".			
F	Have subchronic and/or acute TRVs been used appropriately and have they been properly referenced?					
G	For carcinogens, are TRVs for both cancer and non-cancer end points provided?		Some chemicals can exhibit both threshold and non-threshold effects. Although the non-threshold effect is the most critical response for chronic exposure in most cases, a threshold effect may be more critical for shorter exposure durations. If there is any doubt as to the most critical effect, then risks should be evaluated based on both the threshold and non-threshold effects.			
5. Risk Characterization						
A	Are the results of the risk assessment clearly presented including the identification of COCs with unacceptable risk, if applicable?		The risk assessment report should provide a clear statement of the predicted risks and hazard quotients for each chemical, exposure pathway and critical receptor.			
B	Were any incremental lifetime cancer risks greater than 1×10^{-5} and HQ values > 1.0 (when EDI is known) or >0.2 (when EDI is not known) calculated?		Health Canada considers hazard quotients of 0.2 or less as negligible (or a target HQ of 1 may be used where background EDI is included). If any other agency has been identified as having jurisdiction (for example, provinces for offsite areas), then the acceptable hazard quotient may be different and should be documented in the risk assessment. Health Canada considers risks of one in one hundred thousand (1×10^{-5}) or less as essentially negligible. If another agency has been identified as having jurisdiction (for example, provinces for offsite areas), then the negligible risk level may be different and should be documented in the HHRA.			
i	Were these risks identified as unacceptable?					

FCSAP TRAV SPREADSHEET						
HHRA Sheet						
Site Name: Bar U Ranch National Historic Site near Longview, Alberta FCS# : West Midden (Site 56488004) and East Midden (Site 56488005) DFRP #: 56498 Completed By: Golder Associates Ltd. (TR/JW/MZ) Date Completed: 16/02/2018 Document #: 10						
Question ¹		Response	Rationale/Evidence (document any assumptions, reports, or site-specific information; provide references)	Guidance ¹	Instructions	Flag (for review)
ii	If the risk assessment focused on maximally exposed receptors and risks were deemed unacceptable, were risks to other receptors evaluated?					
C	For threshold-acting chemicals and for non-cancer effects for carcinogens, were HQs assumed to be additive and summed for substances determined to have the same target organ, effect, and mechanism of action?			Hazard quotients should be summed for chemicals that affect the same target organ with the same effect and mode of action. Generally, oral and dermal exposures will be summed, unless there are pathway-specific TRVs.		
D	For carcinogens, have risks been summed for chemicals causing the same form of cancer in the same target organ?			Risks for chemicals that produce the same form of cancer in the same target organ should be summed. Generally, oral and dermal exposures will be summed.		
E	Were the pathways and COCs that drive the risk estimates identified and uncertainties associated with these discussed?					
F	Were risks calculated for all chemicals and receptors of concern identified in the Problem Formulation?					
G	If a target Hazard Quotient of >0.2 was used to identify acceptable risks, were background exposures estimated?			Risks associated with the site and the EDI from background sources could be summed and compared to a target value of 1.0.		
H	Were potential contaminant interactions discussed?			For sites with a mixture of chemicals, additive, synergistic or antagonistic effects should be considered.		
I	If site-specific target levels (SSTLs) were proposed are they supported by the assessment?					
J	Was uncertainty addressed in the risk assessment?			The HHRA should indicate the variables and the assumptions for which the results are the most sensitive.		
i	If Yes, reference applicable section in RA.					

Notes: 1. The questions and guidance are based on Health Canada guidance for human health risk assessment. Additional details can be found in the following documents:

- Federal Contaminated Site Risk Assessment In Canada, Part I: Guidance on Human Health Preliminary Quantitative Risk Assessment (PQRA).
- Federal Contaminated Site Risk Assessment In Canada, Part II: Health Canada Toxicological Reference Values (TRVs).
- Federal Contaminated Site Risk Assessment in Canada, Part III: Guidance on Peer Review of Human Health Risk Assessments for Federal Contaminated Sites in Canada.
- Federal Contaminated Site Risk Assessment in Canada, Part V: Guidance on Human Health Detailed Quantitative Risk Assessment for Chemicals (DORA_{CHEM}).

Limitations: The Tool for Risk Assessment Validation (TRAV) was finalized for Environment Canada and the Federal Contaminated Sites Action Plan (FCSAP) Secretariat in May 2012, under Standing Offer Agreement EN438-070553/003/001/FE. The services performed by Golder Associates Ltd. in the development of TRAV were conducted in a manner consistent with the level of care and skill normally exercised by other members of the science professions currently practicing under similar conditions, subject to the time limits and financial and physical constraints applicable to the services. TRAV is an instrument that was developed to help custodians of federal contaminated sites evaluate the overall quality and completeness of risk assessment work conducted for federal contaminated sites. Its use and/or the result(s) of its use are the strict responsibility of the user(s) of TRAV and no warranty is expressed, implied, or made as to its use and/or result(s). Any use that a third party makes of TRAV or of its output and any reliance on, or decisions made, based on TRAV and its output, are the sole responsibility of such third parties. Golder Associates Ltd. disclaims any responsibility for direct or indirect consequential effects, financial or other, on site management, or requirements for follow-up actions and costs. The TRAV does not provide a legal opinion regarding compliance with applicable laws or regulations.

FCSAP TRAV SPREADSHEET	No quantitative HHRA conducted based on input - do not complete worksheet
HHRA COC Worksheet	See pre-screening section on HHRA worksheet
Site Name:	Bar U Ranch National Historic Site near Longview,
FCSI# :	West Midden (Site 56488004) and East Midden (Si
DFRP #:	56498
Completed By:	Golder Associates Ltd. (TR/JW/MZ)
Date Completed:	16/02/2018
Document #:	10

In Table 1 indicate if each COC was carried forward in the HHRA and provide rationale if the COC was not carried forward. Subsequently, indicate if there was unacceptable risk associated with the COC for each medium.

In Table 2 fill in the receptor/pathway combinations driving the risk estimates for each COC and indicate calculated SSTLs, if applicable.

Note that the 'COCs' tab must be filled in completely, otherwise cells in this table will appear grey.

Table 1 - COCs with unacceptable risk

Media and COCS		Was COC carried forward in HHRA?	If No, provide rationale	Indicate if COC had unacceptable risk						
				Surface Soil	Sub- surface Soil	Groundwater	Surface Water	Sediment	Outdoor Air	Indoor Air
COC #	COC									
1	Arsenic									
2	Iron									
3	Zinc									
4	Manganese									
5	Aluminum									
6	Antimony									
7	Beryllium									
8	Cadmium									
9	Copper									
10	Lead									
11	Molybdenum									
12	Selenium									
13	Zinc									
14	Chlordane									
15	Total PAH									

FCSAP TRAV SPREADSHEET	No quantitative HHRA conducted based on input - do not complete worksheet
HHRA COC Worksheet	See pre-screening section on HHRA worksheet
Site Name:	Bar U Ranch National Historic Site near Longview,
FCSI# :	West Midden (Site 56488004) and East Midden (Si
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Table 2 - Risk Drivers and SSTLs

Media and COCS		Indicate which receptor/pathway combinations are driving risk estimates	SSTL						
			Surface Soil (µg/g)	Subsurface Soil (µg/g)	Groundwater (µg/L)	Surface Water (µg/L)	Sediment (µg/g)	Outdoor Air (µg/m ³)	Indoor Air (µg/m ³)
COC #	COC								
1	Arsenic								
2	Iron								
3	Zinc								
4	Manganese								
5	Aluminum								
6	Antimony								
7	Beryllium								
8	Cadmium								
9	Copper								
10	Lead								
11	Molybdenum								
12	Selenium								
13	Zinc								
14	Chlordane								
15	Total PAH								

Notes	Surface soil risks were obtained from Meridian HHERA (2007), and not evaluated as part of the current DQHHERA. Unacceptable risks will be risk managed by improving the middens caps.
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FCSAP TRAV SPREADSHEET					
ERA Sheet					
Site Name: Bar U Ranch National Historic Site near Longview, Alberta FCS# : West Midden (Site 56488004) and East Midden (Site 56488005) DFRP #: 56498 Completed By: Golder Associates Ltd. (TR/JW/MZ) Date Completed: 16/02/2018 Document #: 10					
Question ¹	Response	Rationale/Evidence (document any assumptions, reports, or site-specific information; provide references)	Guidance ¹	Instructions	Flag (for review)
1. Pre-Screening					
A	Were all maximum measured COC concentrations below environmental check values prior to conducting the RA?	n	Soil related COCs were still considered valid based on the Meridian HHERA (2007) and these will ultimately be risk managed with the recommendation of improving the middens caps. Groundwater, surface water and sediment COCs were also identified in the Phase 2 ESA.	If maximum chemical concentrations are all below the appropriate environmental health based guidelines, then a ERA is not required (i.e., guidelines that are intended to be protective of environmental health, e.g., SQG _E). Note, this is provided that the assumptions that were used to derive the guidelines are valid. If a statistic other than the maximum measured concentration was used, please provide rationale/reference.	Complete ERA and ERA_COC tabs.
B	Was the ERA conducted pre-remediation?	y	ERA was conducted pre-remediation.		
C	Has Expert Support reviewed the ERA?	n	Expert Support has yet to review the DQHHERA.	Note that TRAV may still be completed even if Expert Support has reviewed the RA.	
i	Please provide Expert Support author(s), department(s), date(s) and title(s)				
ii	Were Expert Support comments incorporated or considered in the ERA? If no, provide rationale				
D	Is the site close to a water body or does it include a water body?	y	Pekisko Creek is approximately 140 m from the closest midden.	For the purpose of TRAV, answer Yes if there is a water body within 5 km.	
i	Were aquatic receptors considered in the ERA?	y	Aquatic receptors were considered in the ERA.	The user should indicate if aquatic receptors were considered in the ERA, given the proximity to a water body. Rationale should be provided if aquatic receptors were not considered.	
ii	Was the assessment of risks to aquatic receptors conducted qualitatively?	y	The Tier 1 Screening and subsequent statistical approach (i.e., Wilcoxon Rank Sum Test) identified no COCs in groundwater, surface water and sediment for aquatic receptors; as such a qualitative assessment of risks was completed	Provide rationale for assessing aquatic receptors qualitatively, if yes.	If qualitative, provide rationale.
iii	Were there unacceptable risks associated with aquatic receptors based on the qualitative assessment?	n	No COCs were retained based on the Tier 2 Screening and subsequent statistical analysis (i.e., Wilcoxon Rank Sum Test); as such, risks to aquatic life were considered to be acceptable.	Describe the nature of the unacceptable risks in the rationale box. The information will be included in the Summary Sheet and the remainder of the TRAV aquatic receptor questions will not have to be answered.	
E	Were terrestrial receptors considered in the ERA?	y	Terrestrial receptors were considered in the ERA.	The user should indicate if a terrestrial receptors were considered in the ERA.	
i	Was the assessment of risks to terrestrial receptors conducted qualitatively?	n	No COCs were retained based on the Tier 1 Screening and subsequent statistical analysis (i.e., Wilcoxon Rank Sum Test); as such, risks to terrestrial receptors were considered to be acceptable in the DQHHERA. However, the Meridian (2007) HHERA indicated that unacceptable risks exist for terrestrial receptors (wildlife, plants and soil invertebrates, livestock) exposed to metals, PAHs and chlordanes in soil. These will ultimately be risk managed with the recommendation of improving the middens caps.	Provide rationale for assessing terrestrial receptors qualitatively, if yes.	
ii	Were there unacceptable risks associated with terrestrial receptors based on the qualitative assessment?			Describe the nature of the unacceptable risks in the rationale box. The information will be included in the Summary Sheet and the remainder of the TRAV terrestrial receptor questions will not have to be answered.	
F	Did the risk assessor identify any major limitations with respect to the site characterization data, given the nature of the data and the hypothesis on contaminant distribution such that it might limit the conclusions of the ERA?	n	No major limitations were identified.		
i	Did the risk assessor address the potential limitations from site characterization data in the conclusions of the risk assessment?				
G	What land use was the ERA based on?	agricultural land use.			
H	Describe any site use restrictions based on assumptions made in the risk assessment.	No site restrictions were identified.			
				Indicate any site use restrictions (e.g., no buildings on site, etc.).	

FCSAP TRAV SPREADSHEET					
ERA Sheet					
Site Name: Bar U Ranch National Historic Site near Longview, Alberta FCS# : West Midden (Site 56488004) and East Midden (Site 56488005) DFRP #: 56498 Completed By: Golder Associates Ltd. (TR/JW/MZ) Date Completed: 16/02/2018 Document #: 10					
Question ¹	Response	Rationale/Evidence (document any assumptions, reports, or site-specific information; provide references)	Guidance ¹	Instructions	Flag (for review)
2. Problem Formulation					
Objectives					
A	Are the site management goals clearly stated?	y	The site management goals were stated in the Meridian HHERA (2007) and again in the DQHHERA: risk management is required to improve the middens cap and block unacceptable soil-related exposure	The site management goals should be clear as well as how the ERA was used to support site management decisions.	
i	Is it clear how the ERA was used to support the site management goals?	y	The scope of work and subsequent risk assessment sections support the study objectives		
ii	Provide report reference where site management goals are stated.	Meridian Environmental Inc. (Meridian), 2007. Human Health and Ecological Risk Assessment, Former Waste Disposal Middens, Bar U Ranch National Historic Site. March 14, 2007. File No. 11005			
B	Have all assessment endpoints been identified clearly?	y	All assessment endpoints were identified clearly in Meridian HHERA (2007)	An assessment endpoint describes an attribute of a receptor or receptor group (e.g., ecological function of the soil invertebrate community)	
C	Have all measurement endpoints been identified clearly and do they support the assessment endpoints?	y	All measurement endpoints support the assessment endpoints	Measurement endpoints are the tools used to measure exposure for, or effects on, a receptor, or to measure changes in attributes of assessment endpoints.	
Habitat Assessment					
D	Was an on-site habitat assessment completed? Provide a brief description of on-site habitat in the rationale box.	y	On-Site habitat assessment was completed as part of the current DQHHERA as well as previous investigations	The type of habitat at the site and adjacent to the site should be evaluated in the ERA (e.g., surface water, river, stream, lake, estuary, marine, wetland, woodlands, fallow field, manicured lawn, etc.), as well as ROCs that may be present.	Provide information on habitat in rationale cell
E	Was an adjacent habitat assessment completed? Provide a brief description of adjacent habitat in the rationale box.	y	An aquatic habitat assessment was completed for Pekisko Creek which is an adjacent habitat from the middens		Provide information on habitat in rationale cell
F	If there is more than one type of habitat in an area (e.g., riparian, aquatic, upland forested, prairie grassland etc.), were all habitat types on the site considered in the risk assessment?	y	An aquatic habitat assessment was completed for Pekisko Creek		
i	Which habitats were excluded? Provide rationale.				
G	Were both on and offsite (occasional) receptors considered?	y	On and off-Site receptors were considered given no barriers currently limit access to the Site.		
H	Did the ERA include a comparison to reference sites, a gradient design or background conditions to establish that adverse effects are related to contamination?	y	Reference samples were collected as part of the DQHHERA and the ERA included a comparison of on-Site concentrations to reference concentrations using a statistical approach (i.e., Wilcoxon Rank Sum Test)	A reference site should reflect the ambient physical and chemical conditions of a site in the absence of the stressors of concern in the risk assessment. For example, in a study of soil contamination, a reference site should be chosen to depict the climate, substrate, and habitat factors relevant to the site but with no incremental contamination relative to background conditions. In some cases, the term reference may be used in the context of an altered background condition (i.e., where the local conditions surrounding a site are not pristine).	
Species at Risk					
I	Was a Species at Risk (SAR) assessment conducted for the site?	y	A Species at Risk Assessment was completed as part of the DQHHERA and the Meridian HHERA (2007).	Species at risk require specific consideration in an ERA and should be identified and assessed. For example, the protection goal defined for a listed species (e.g., a rare or endangered species) may be much different than for a common species, because the Species at Risk Act requires protection of individual organisms of a listed species, whereas for some common species an ERA may aim for protection at population level.	
i	Were SAR identified as potential or actual ROCs?	y	SAR were identified as actual ROCs.		
ii	Were SAR carried through the assessment and specifically considered in the ERA?	y	SAR were carried through the assessment.	Note that the SAR assessment may have been conducted in previous reports - any SAR identified should be carried forward and considered in the ERA.	
CSM					
J	Was a CSM included in the ERA?	y	A CSM was included.	The CSM is a written description and visual representation of predicated relationships between stressors and assessment endpoints.	
i	Does the CSM identify the interactions between receptors and key stressors (usually COCs, but sometimes physical stressors)?	y	The CSM identifies interactions between COC-exposure pathway-receptor combinations that are complete for the Site.	The CSM should illustrate the linkages between COCs, ROCs and exposure pathways and also consider the potential fate and transport of contaminants. Where exposure pathways are excluded, a rationale should be provided in the ERA. The complexity of the CSM should be in keeping with the level of complexity of the ERA.	

FCSAP TRAV SPREADSHEET					
ERA Sheet					
Site Name: Bar U Ranch National Historic Site near Longview, Alberta FCS# : West Midden (Site 56488004) and East Midden (Site 56488005) DFRP #: 56498 Completed By: Golder Associates Ltd. (TR/JW/MZ) Date Completed: 16/02/2018 Document #: 10					
Question ¹	Response	Rationale/Evidence (document any assumptions, reports, or site-specific information; provide references)	Guidance ¹	Instructions	Flag (for review)
3. Exposure Assessment					
A	Was a model or equations used to predict environmental concentrations?	y	The Meridian HHERA (2007) considered food chain modeling to predict concentrations in different food items for wildlife receptors. This was not completed as part of the current DQHHERA as no COCs were ultimately retained for groundwater, surface water or sediment.	Environmental fate models or equations may be used to estimate or predict the concentration in one medium based on measured concentrations in another medium (e.g., estimating groundwater concentrations from soil concentrations, predicting indoor air concentrations from soil or groundwater concentrations, predicting a concentration in food sources based on soil concentrations).	
i	If a model or equations were used to predict environmental concentrations, was their use appropriate, were all input parameters justified, were assumptions explained and were references provided?	y	Modeling was appropriately used for the Meridian HHERA (2007) associated with soil exposure, however, it was not completed as part the current DQHHERA as no COCs were ultimately retained for groundwater, surface water or sediment.		
ii	Have model predicted values been calibrated to or compared against measurement data from the site? Do the comparisons of model predictions make sense?	y			
B	Was home range size incorporated into the assessment?	y	Home range was incorporated for the Meridian HHERA (2007) associated with soil exposure, however, it was not completed as part the current DQHHERA as no COCs were ultimately retained for groundwater, surface water or sediment.	Home range size of each receptor relative to the size of the site (or relevant portion of the site). The home range size should be estimated based on an up to date literature review, but can be adjusted based on professional judgment of a wildlife biologist (e.g., if habitat quality is low, range size may be larger).	
i	Was the source of the home range size documented?	y	Source for home range size was documented for the Meridian HHERA (2007) associated with soil exposure, however, it was not completed as part the current DQHHERA as no COCs were ultimately retained for groundwater, surface water or sediment.		
C	For higher order receptors, was receptor characteristic information presented and referenced? (e.g., ingestion rate, diet proportions, body weight, home range size, etc.)	y	Higher order receptor characteristics were presented and referenced.	Receptor characteristic information is provided in the Receptor Characteristics Module of the FCSAP ERA guidance.	
D	Was uptake through the food chain adequately addressed?	y	Uptake through food chain was adequately addressed through food chain modeling calculations for the Meridian HHERA (2007) associated with soil exposure, however, it was not completed as part the current DQHHERA as no COCs were ultimately retained for groundwater, surface water or sediment.	For example, food chain linkages and uptake equations to estimate exposure in higher trophic levels should be explained.	
E	Were contaminant hot spots or preferred habitat features considered as factors that could affect the level of exposure?	n	No contaminant hotspots were identified for the Site.	If there are hot spots or areas of preferred ROC habitat, this may affect exposure level and could be considered in the ERA. See FCSAP ERA guidance related to spatial realism for additional information.	
4. Effects Assessment					
A	Was the effects assessment compatible with the measurement endpoints defined in the problem formulation?	y			
B	Were potential contaminant interactions discussed in the effects assessment?	y	Potential contaminant interactions associated with soil exposure were discussed in the Meridian report (2007). No COCs were retained as part of the current DQHHERA in groundwater, surface water and sediment. Therefore, potential interactions were not discussed.	For sites with mixtures of chemicals, additive, synergistic or antagonistic effects should be considered. Careful review of available literature and best professional judgement is required to justify the assessment of contaminant interactions. Project specific studies may be required to evaluate contaminant interactions.	
C	Were site-specific TRVs derived for the ERA?	n	Standard TRVs typically used for ERAs were applied for the Meridian HHERA (2007) associated with soil exposure, however, it was not completed as part the current DQHHERA as no COCs were ultimately retained for groundwater, surface water or sediment.		
i	Were TRVs derived in accordance with EC guidance? (If no, provide rationale)			EC guidance is found in the document: Selection or Development of Site-specific Toxicity Reference Values, which is Technical Module B to the FCSAP ERA Guidance	
ii	If no, document guidance used.				

FCSAP TRAV SPREADSHEET					
ERA Sheet					
Site Name: Bar U Ranch National Historic Site near Longview, Alberta FCS# : West Midden (Site 56488004) and East Midden (Site 56488005) DFRP #: 56498 Completed By: Golder Associates Ltd. (TR/JW/MZ) Date Completed: 16/02/2018 Document #: 10					
Question ¹	Response	Rationale/Evidence (document any assumptions, reports, or site-specific information; provide references)	Guidance ¹	Instructions	Flag (for review)
5. Risk Characterization					
A	Were the objectives of the study addressed? For any objectives not addressed, list and provide rationale along with further actions required.	y	Objectives were addressed.		
B	Are the results of the risk assessment clearly presented including the identification of COCs with unacceptable risk, if applicable?	y	Results of the Meridian HHERA (2007) were clearly presented with respect to soil. Results of the current DQHHERA were also clearly presented, however risks associated with groundwater, surface water and sediment were considered to be acceptable.		
C	Did the RA determine that effects are related to a non-chemical stressor (e.g., physical stressor) as opposed to chemical stressor?	n		A stressor is any substance or process that may cause an undesirable response to the health or biological status of an organism.	
D	Was a weight of evidence approach used?	y	Quantitative estimates of risk and consideration of terrestrial vegetative health were applied in the Meridian HHERA (2007). The current DQHHERA identified no COCs for groundwater, surface water or sediment. Therefore, a weight of evidence approach was not completed.	The weight of evidence approach should be consistent with the guidance provided in the FCSAP ERA Guidance document, the Canada-Ontario Decision Making Framework for Assessment of Great Lakes Sediment (2008) or the Aquatic Sites Framework. The ERA should clearly outline the various lines of evidence that were used in the assessment (e.g., chemistry, toxicity, benthic community alteration and biomagnification potential).	
i	Were multiple lines of evidence presented?	y	Quantitative estimates of risk were identified, however vegetative health was also considered as a line of evidence in the Meridian HHERA (2007). The current DQHHERA identified no COCs for groundwater, surface water or sediment. Therefore, multiple lines of evidence were not presented.		
ii	Was the weighting of the LOE clearly documented?	y	Weighting of LOE was clearly documented in the Meridian HHERA (2007). The current DQHHERA identified no COCs for groundwater, surface water or sediment. Therefore, multiple lines of evidence were not presented.		
iii	Were the LOE integrated and weighted to provide overall risk characterization?	y	Both LOEs above were used in the interpretation of risks.		
iv	Was this clearly documented and transparent?	y			
v	Were all individual LOE considered in the weighting?	y			
E	If site-specific target levels (SSTLs) were proposed, are they supported by the assessment?	y	SSTLs were determined in the Meridian HHERA (2007) for soil, however, no SSTLs were determined as part of the current DQHHERA.		
F	Was uncertainty addressed in the risk assessment?	y		The ERA should indicate the variables and the assumptions for which the results are the most sensitive.	
i	If Yes, reference applicable section in RA.	Section 9.0 of the Meridian HHERA (2007) provides this information			

Notes: 1. The questions and guidance are based on FCSAP ERA Guidance. Additional details can be found in the following documents:

FCSAP Ecological Risk Assessment Guidance, Environment Canada, 2012

FCSAP TRAV SPREADSHEET ERA ROC Spreadsheet						Instructions:						
Site Name: Bar U Ranch National Historic Site near Longview, Alberta FCS#: West Midden (Site 56488004) and East Midden (Site 56488005) DFRP #: 56498 Completed By: Golder Associates Ltd. (TR/JW/MZ) Date Completed: 16/02/2018 Document #: 10						1. For each receptor group, indicate if the receptor group was included in the ERA in Column C. If not included, provide rationale in Column D. 2. Indicate surrogate ROCs selected for the assessment. If the receptor group was assessed as a community, input "Community" as a surrogate receptor. There is space for up to 3 surrogate ROCs. If more were assessed in the ERA, include only those that were considered drivers for the ERA. Additional notes can be recorded at the bottom of the worksheet. 3. List the assessment endpoint(s) for each receptor or receptor group. 4. Indicate which media the ROC are exposed to by selecting y in the applicable orange boxes in columns G through N. 5. List lines of evidence used to assess effects to receptor groups in Column O. 6. An example is provided in rows 11-13.						
Receptor Group	Receptor Type	Receptor Group included in the ERA (Y/N)?	If Receptor Group not included, provide rationale.	If Yes, was relevant surrogate ROC selected? See Reference Material for examples of Surrogate Receptors List up to 3 surrogates. Note that "Community" may be listed as a surrogate	List assessment endpoints for each receptor or receptor group See Reference material for examples of Assessment Endpoints	Indicate if ROC is exposed to the following media						List Lines of Evidence considered that are associated with the receptor groups
						Surface Soil	Sub Surface Soil	Groundwater	Surface water	Sediment	Outdoor Air	
Example: Benthic Invertebrate	Epifauna, Infauna	y		Community	Macroinvertebrate community structure and function				y	y		Comparison of sediment concentrations to criteria or guidelines
				Crayfish	Crayfish population viability and maintenance				y	y		Field study of benthic invertebrate community composition
												Field study of crayfish abundance relative to reference conditions
Aquatic Ecosystems												
Primary Producer	Phytoplankton, Periphyton, Macrophyte											
Pelagic Invertebrate	Zooplankton, Others											
Benthic Invertebrate	Epifauna, Infauna											
Fish ¹	Benthivorous, Planktivorous, Piscivorous											
Mammal	Herbivorous, Piscivorous, Omnivorous											
Bird	Herbivorous, Insectivorous, Piscivorous, Omnivorous											
Amphibian	Carnivorous											
Reptile	Omnivorous											

<p>FCSAP TRAV SPREADSHEET ERA ROC Spreadsheet</p> <p style="text-align: center;">Site Name: Bar U Ranch National Historic Site near Longview, Alberta FCS#: West Midden (Site 56488004) and East Midden (Site 56488005) DFRP #: 56498 Completed By: Golder Associates Ltd. (TR/JW/MZ) Date Completed: 16/02/2018 Document #: 10</p>	<p>Instructions:</p> <ol style="list-style-type: none"> For each receptor group, indicate if the receptor group was included in the ERA in Column C. If not included, provide rationale in Column D. Indicate surrogate ROCs selected for the assessment. If the receptor group was assessed as a community, input "Community" as a surrogate receptor. There is space for up to 3 surrogate ROCs. If more were assessed in the ERA, include only those that were considered drivers for the ERA. Additional notes can be recorded at the bottom of the worksheet. List the assessment endpoint(s) for each receptor or receptor group. Indicate which media the ROC are exposed to by selecting y in the applicable orange boxes in columns G through N. List lines of evidence used to assess effects to receptor groups in Column O. An example is provided in rows 11-13.
--	--

Receptor Group	Receptor Type	Receptor Group included in the ERA (Y/N)?	If Receptor Group not included, provide rationale.	If Yes, was relevant surrogate ROC selected? <i>See Reference Material for examples of Surrogate Receptors</i> List up to 3 surrogates. Note that "Community" may be listed as a surrogate	List assessment endpoints for each receptor or receptor group <i>See Reference material for examples of Assessment Endpoints</i>	Indicate if ROC is exposed to the following media						List Lines of Evidence considered that are associated with the receptor groups
						Surface Soil	Sub Surface Soil	Groundwater	Surface water	Sediment	Outdoor Air	

Terrestrial Ecosystems												
Primary Producer	Moss/Grass/Shrub/Tree	y		Plant Community		y	n					
Invertebrates/soil microbes	Ground-dwelling, Aerial, Soil Microbes	y		Soil Invertebrate Community		y	n					
Mammal	Herbivorous, Insectivorous, Piscivorous, Omnivorous	y		Mammals		y	n					
Bird	Herbivorous, Insectivorous, Piscivorous, Omnivorous	y		Birds		y	n					
Amphibian	Carnivorous	y		Boreal Chorus Frog		y	n					
Reptile	Omnivorous	n	No reptiles were considered in Meridian HHERA (2007)									

Notes:

Source:
FSCAP Supplemental Guidance for Ecological Risk Assessment, Environment Canada, 2012

Notes:

1 - The Receptor Types for the Receptor Group "Fish" for the purpose of completing TRAV are defined as cold blooded aquatic vertebrates of the Superclass *Pisces* of any age group (juvenile, fry, adult). Note that this is not the Fisheries Act definition of 'fish'.

FCSAP TRAV SPREADSHEET
ERA COC Worksheet

Site Name: Bar U Ranch National Historic Site near Longview, Alberta
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Instructions:
 In Table 1, indicate if each COC was carried forward in the ERA and provide rationale if the COC was not carried forward. Subsequently, indicate if there was unacceptable risk associated with the COC for each medium.
 In Table 2, fill in the ROCs and pathways driving the risk estimates for each COC. Select ROCs from drop down list (based on ROCs entered previously on ERA_ROC sheet). Type in the information for the pathways associated with the ROCs.
 In Table 3, indicate calculated SSTLs, if applicable.

Table 1: COCs and Unacceptable Risk

COC		Was COC carried forward in ERA?	If no, provide rationale	Indicate if COC had unacceptable risk
COC #	COC			
1	Arsenic	y		n
2	Iron	n	Not a COC for ERA	
3	Zinc	n	Not a COC for ERA	
4	Manganese	n	Not a COC for ERA	
5	Aluminum	y		y
6	Antimony	y		y
7	Beryllium	y		n
8	Cadmium	y		n
9	Copper	y		y
10	Lead	y		y
11	Molybdenum	y		n
12	Selenium	y		y
13	Zinc	y		y
14	Chlordane	y		n
15	Total PAH	y		y

FCSAP TRAV SPREADSHEET							
ERA COC Worksheet							
Site Name: Bar U Ranch National Historic Site near Longview, Alberta FCSI#: West Midden (Site 56488004) and East Midden (Site 5648800) DFRP #: 56498 Completed By: Golder Associates Ltd. (TR/JW/MZ) Date Completed: 16/02/2018 Document #: 10							
Table 2: ROCs and Pathways with Unacceptable Risk							
COC							
Select ROC for which there was unacceptable risk (only receptors exposed to a media are listed)							
COC #	ROC 1	Pathway(s)	ROC 2	Pathway(s)	ROC 3	Pathway(s)	Additional ROC(s) and Pathway(s)
1	Arsenic						
2	Iron						
3	Zinc						
4	Manganese						
5	Aluminium	Mammals	direct contact/soil/prey ingestion	Birds	direct contact/soil/prey ingestion		
6	Antimony	Mammals	direct contact/soil/prey ingestion	Birds	direct contact/soil/prey ingestion		
7	Beryllium						
8	Cadmium						
9	Copper	Plant Community	Direct contact	Soil Invertebrate Community	Direct contact		
10	Lead	Plant Community	Direct contact	Soil Invertebrate Community	Direct contact	Mammals	direct contact/soil/prey ingestion
11	Molybdenum						
12	Selenium	Plant Community	Direct contact	Soil Invertebrate Community	Direct contact		
13	Zinc	Plant Community	Direct contact	Soil Invertebrate Community	Direct contact	Mammals	direct contact/soil/prey ingestion
14	Chlordane						
15	Total PAH	Plant Community	Direct contact	Soil Invertebrate Community	Direct contact		

FCSAP TRAV SPREADSHEET

ERA COC Worksheet

Site Name: Bar U Ranch National Historic Site near Longview, Alberta
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Table 3: Site Specific Target Levels (SSTLs)

COC		SSTLs						
		Surface Soil (µg/g)	Subsurface Soil (µg/g)	Groundwater (µg/L)	Surface Water (µg/L)	Sediment (µg/g)	Outdoor Air (µg/m ³)	Indoor Air (µg/m ³)
COC #	COC							
1	Arsenic							
2	Iron							
3	Zinc							
4	Manganese							
5	Aluminum							
6	Antimony	78						
7	Beryllium							
8	Cadmium							
9	Copper	63						
10	Lead	70						
11	Molybdenum							
12	Selenium	1						
13	Zinc	200						
14	Chlordane							
15	Total PAH							

Notes: Soil risks were obtained from Meridian HHERA (2007), and not evaluated as part of the current DQHHERA. Unacceptable risks will be risk managed by improving the middens caps.

FCSAP TRAV SUMMARY PART 1

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 Date Completed: 16/02/2018
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This worksheet summarizes if major and minor deficiencies were noted during the completion of the TRAV. Also, a summary of the results of the HHRA and ERA are provided. Major deficiencies are listed.
 The custodian project manager has the opportunity to review or analyze the major deficiencies and determining if the risk assessment is acceptable.
 The custodian project manager should also review rationale provided where answers indicate that guidance was not followed. These questions/answers are indicated with a green dot.

Summary of Results of RA Validation

Summary of Major Deficiencies

> Were any major deficiencies noted:	No	
> Were major deficiencies reviewed by custodian project manager?	No	Answer yes or no, if applicable (major deficiencies are listed below) Custodian project manager should also review rationale provided.
> Please provide custodian project manager name(s), department(s), date(s) and title(s)	The DQHHERA has not yet been reviewed.	
> After review (if applicable), did major deficiencies remain?	No	Answer yes or no.
> Please provide details on yes/no answer	The DQHHERA has not yet been reviewed.	
Overall TRAV result (Pass/Fail)	Pass	*This answer gets incorporated in the SCT

Summary of Unacceptable Risks

> Was there unacceptable risk for the HHRA?	Yes
> Was there unacceptable risk for the ERA?	Yes

Summary of Land Use and Site Use Restrictions

> What land use was the HHRA based on?	
> Site use restrictions based on assumptions made in the HHRA risk assessment.	
> What land use was the ERA based on?	agricultural land use.
> Site use restrictions based on assumptions made in the ERA risk assessment.	No site restrictions were identified.

FCSAP TRAV SUMMARY PART 1

Site Name: Bar U Ranch National Historic Site near Longview, Alberta
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Sources of Contamination:

User defined source 1

Quantitative HHRA Not Completed

ERA Summary

COCS	Was COC carried forward in ERA?	Did COC have unacceptable risk?	Receptors of Concern and pathways for which there was unacceptable risk	SSTLs
Arsenic	Yes	No		
Iron	No			
Zinc	No			
Manganese	No			
Aluminum	Yes	Yes	Mammals - Direct contact/soil/prey ingestion Birds - Direct contact/soil/prey ingestion	
Antimony	Yes	Yes	Mammals - Direct contact/soil/prey ingestion Birds - Direct contact/soil/prey ingestion	Surface Soil: 78 µg/g
Beryllium	Yes	No		
Cadmium	Yes	No		
Copper	Yes	Yes	Plant Community - Direct contact Soil Invertebrate Community - Direct contact	Surface Soil: 63 µg/g
Lead	Yes	Yes	Plant Community - Direct contact Soil Invertebrate Community - Direct contact Mammals - Direct contact/soil/prey ingestion Birds - direct contact/soil/prey ingestion	Surface Soil: 70 µg/g
Molybdenum	Yes	No		
Selenium	Yes	Yes	Plant Community - Direct contact Soil Invertebrate Community - Direct contact	Surface Soil: 1 µg/g
Zinc	Yes	Yes	Plant Community - Direct contact Soil Invertebrate Community - Direct contact Mammals - Direct contact/soil/prey ingestion Birds - direct contact/soil/prey ingestion	Surface Soil: 200 µg/g
Chlordane	Yes	No		
Total PAH	Yes	Yes	Plant Community - Direct contact Soil Invertebrate Community - Direct contact	

Deficiencies

FCSAP TRAV SUMMARY PART 2

Site Name: Bar U Ranch National Historic Site near Longview, Alberta
 FCSI#: West Midden (Site 56488004) and East Midden (Site 56488004)
 DFRP #: 56498
 Completed By: Golder Associates Ltd. (TR/JW/MZ)
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Overall SSTLs or maximum allowable concentrations that will be left in place at the Site should be recorded in the table. The buttons to the right of the table autopopulate the table with data previously entered in the HHRA and ERA worksheets.

For each COC, enter either the SSTL if applicable, or the maximum allowable concentration with acceptable risk either manually or using the buttons. Data should be entered for each orange cell. This information will be forwarded to the SCT.

Overall SSTL Or Maximum Allowable Concentration With Acceptable Risk

COC	Surface Soil (µg/g)	Subsurface Soil (µg/g)	Groundwater (µg/L)	Surface Water (µg/L)	Sediment (µg/g)	Outdoor Air (µg/m ³)	Indoor Air (µg/m ³)
Arsenic							
Iron							
Zinc							
Manganese							
Aluminum							
Antimony	78						
Beryllium							
Cadmium							
Copper	63						
Lead	70						
Molybdenum							
Selenium	1						
Zinc	200						
Chlordane							
Total PAH							

Notes: No unacceptable risks were identified for human health and the environment for the Site associated with groundwater, surface water or sediment exposure; as such, SSTLs were not derived as part of the current DQHERA.