Associated Environmental

REPORT

Government of Northwest Territories

Tin Can Hill, Yellowknife, NT
Remedial Options Analysis
2023-8451

MAY 2024

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EXECUTIVE SUMMARY

The Government of Northwest Territories retained Associated Environmental Consultant Inc. (Associated) to provide a remedial options analysis (ROA) for Tin Can Hill in Yellowknife, NT (Subject Site). Associated evaluated remedial options based on cost, feasibility, time frame, health and safety considerations, and availability of local and qualified contractors. The focus of the ROA is to estimate the environmental liabilities at the Subject Site and review the potential options for remediation to prepare the site for future redevelopment as a polytechnic university. The concepts in the polytechnic university facilities master plan (FMP) provided the potential development footprint.

This ROA is based on the results of Associated's 2024 Phase II/III Environmental Site Assessment (ESA) and the 2024 preliminary quantitative risk assessment (PQRA) completed by Steer Environmental Associates Ltd. (Steer). The Phase II/III ESA identified widespread metals contamination (i.e., antimony, arsenic, barium, copper, selenium, and zinc) in surface soil across the Subject Site. The soil sampling was based on a roughly 50 m grid where soil was present. The surface of the Subject Site consists primarily of bedrock outcrops interspersed with mineral soil and vegetation.

The PQRA used soil data from the Phase II/III ESA in its risk calculations. The PQRA determined that arsenic in soil posed an unacceptable health risk to residents of a future university and to regular toddler (<5 years old) patrons of a university daycare. These unacceptable risks would be located at proposed residences, outdoor gathering areas, and a toddler daycare (i.e., sensitive areas). Contaminants in soil did not pose an unacceptable risk to non-resident university students, faculty, or staff, or to children (>5 years old) as full-time university daycare patrons. The PQRA concluded there was a high likelihood that human health risks were overestimated. It also identified a potential ecological risk, but with a moderate to high uncertainty, that likely overestimated the risk.

At a minimum, before any campus construction can begin, the PQRA must be updated to adequately address human health risks. The current gaps for human health protection are:

- The PQRA does not consider the consumption of natural vegetation.
- The PQRA recommends additional soil sampling along the Old Mine Road (OMR)that crosses the campus footprint.

The estimated costs are budgetary in nature and are provided for planning purposes only.

The following remedial options were considered:

1. Do not construct on-site residences or a toddler daycare:
   - Unacceptable risks were calculated to be present only for university residents or toddler daycare patrons.
   - This option would remove the only unacceptable human health risks identified in the PQRA.
   - Development may be feasible after completing additional environmental sampling of the OMR and of any edible vegetation to assess the human health risks in the PQRA.
2. Conduct additional intensive soil sampling at the proposed locations of residences, outdoor gathering areas, and the toddler daycare to support risk assessment:
   - The current risk assessment is based on soil samples located approximately 50 m apart and only broadly characterizes the metals concentrations in the area.

- Collecting approximately 20 additional samples (roughly 10 m grid) in sensitive development areas would provide a defensible amount of data to estimate the risks for each decision area.
- More accurately determine whether unacceptable risks are actually present and increase the confidence of the risk assessment, which currently likely overestimates the human health risk.
- This information, along with additional environmental sampling of the OMR and of any edible vegetation, would be used to update the PQRA and confirm acceptable development options.

3. Cap the proposed locations of residences, outdoor gathering areas, and the toddler daycare with clean fill:
    - The proposed residence and daycare areas would be capped with 1 m of clean fill.
    - Fill would provide a barrier to prevent exposure to the underlying metals-contaminated soil.
    - Contouring of building locations may be required to support building construction on the property given the unevenness of the bedrock.
    - Capping and additional environmental sampling of the OMR and of any edible vegetation would be used to update the PQRA and confirm acceptable development options.
4. Remove the contaminated surface soil at the proposed locations of residences, outdoor gathering areas, and the toddler daycare and backfill with clean material:
    - Due to the bedrock terrain, traditional remediation techniques (i.e., using an excavator) are not feasible.
    - Physical remediation of contaminated soil may be possible using a hydrovac truck to remove the soil from the exposed bedrock.
    - Truck vacuums may be sufficient to remove loose dry soils, but any clayey or compacted soil would need to be broken apart first.
    - A labour crew would need to manually break apart soil and avoid using high-pressure water wands. This option would involve the subsequent disposal costs of the generated slurry.
    - Truck access is limited to the single road leading to the water treatment plant, and the farther proposed developments are approximately 300 m away, beyond the maximum reach of remote hose.
    - Without additional road construction, other remediation methods will be required for the areas beyond the reach of remote hose.
    - Excavation sampling would be required to confirm remediation success.
    - These sampling results, along with additional environmental sampling of the OMR and of any edible vegetation, would be used to update the PQRA and confirm acceptable development options.

One of the guiding principles of the FMP is that the existing natural environment should remain as part of campus development and that existing vegetation should be maintained, where possible. Given this tenet and as the PQRA has likely overestimated the human health risks at the Subject Site, additional sampling to update the PQRA is the recommended option. The two sampling options are:

- Intensive sampling in specific development areas to refine the risk assessment before residences and a toddler daycare could be constructed.
- If these facilities are removed from the development plans, then less environmental sampling is required to update the PQRA before construction can proceed.

There is no guarantee that the findings of the additional investigation will favourably support the risk assessment. Unfavourable results that do not support the risk assessment would still provide a better understanding of the contamination extents for other remedial options, such as capping or soil removal. This ROA should be reassessed as any new relevant information, such as environmental investigation or construction techniques, becomes available.

Note that blasting was required to create a level foundation for constructing the nearby water treatment plant at the north end of Tin Can Hill. If similar construction techniques are required for the residences and daycare, disposal of the blasting rubble may remove most or all contaminated soil in those development areas. The cost of blasting is beyond the scope of this ROA.

The estimated costs for the recommended options are between $30,000 and $60,000. The costs for each task are summarized in Table 1.

Table 1
Recommended Options Cost Estimate

	Task	Cost
1 – Do not construct residences or toddler daycare	Limited sampling to update PQRA: Field visit for sampling and reporting - $22,000 Risk assessment reporting - $5,000 10% contingency - $2,700	$29,700
2 – Refine risk assessment to support residences and toddler daycare	Conduct intensive sampling to update PQRA: Field visit for sampling and reporting - $47,000 Risk assessment reporting - $7,500 10% contingency - $5,450	$59,950

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1 INTRODUCTION

The Government of Northwest Territories (GNWT) retained Associated Environmental Consultants Inc. (Associated) to provide a remedial options analysis (ROA) for Tin Can Hill in Yellowknife, NT.

The objective of the ROA is to provide remedial options for the arsenic contamination in soil identified in the Phase II/III Environmental Site Assessment (ESA) (Associated 2024). Associated evaluated the remedial options based on cost, feasibility, time frame, health and safety considerations, and availability of local and qualified contractors. The focus of the ROA is to estimate the environmental liabilities on site and review the potential options for remediation to prepare the site for future redevelopment.

2 BACKGROUND

2.1 Site Description

The Subject Site is Tin Can Hill, Yellowknife, NT (Figure 1):

- Civic address: Part of the 101 Tin Can Way property
- Legal land description: Lot 10, Block 203, Plan 4460
- Latitude and longitude: Site centre is at approximately 62°26′49″ N, 114°21′18″ W
- The property is approximately 28.7 ha in total, and the northern 10.9 ha are proposed for redevelopment as a polytechnic university.
- Except for a single gravel roadway (the Old Mine Road [OMR]), the property is undeveloped and is used by the public as a recreation area.
- The ground surface consists of exposed bedrock interspersed with mineral soil that supports native vegetation.
- Cleared dirt walking trails, with constructed boardwalks over boggy/marshy areas, are located across the Subject Site.

2.2 Phase I ESA

In November 2023, Associated completed a Phase I ESA for the Subject Site (Associated 2023). The Phase I ESA identified a moderate potential that historical land use activities on site or on surrounding properties have resulted in soil contamination at the Subject Site.

2.3 Phase II/III ESA

In March 2024, Associated completed a Phase II/III ESA for the Subject Site (Associated 2024). The scope of work completed by Associated included the following activities:

- Collecting soil samples at 37 locations across the Subject Site from surface to a maximum depth of 0.4 m below ground surface (mbgs) using a shovel or trowel;
- Collecting five surface soil and/or gravel samples along the OMR (approximately every 100 m, from surface to a maximum of 0.1 mbgs) using a shovel or trowel;
- Collecting two surface water samples from adjacent surface waterbodies;

- Submitting soil and water samples to an accredited laboratory for analysis of potential contaminants of concern;
- Comparing soil and water data to the applicable guidelines; and
- Compiling data and preparing a report summarizing the results and providing recommendations.

Based on the results of the Phase II/III ESA, Associated provided the following conclusions:

- Widespread metals contamination consisting of antimony, arsenic, barium, copper, selenium, and zinc was identified in soil across the Subject Site when soil concentrations were compared to the Environmental Guideline for Contaminated Site Remediation (EGCSR) (GNWT 2003).
- Additional soil contamination was identified (i.e., boron, cobalt, and vanadium) when soil concentrations were compared to the 2023 draft EGCSR (GNWT 2023).
- Based on the laboratory metals leachate analysis, all soil is suitable for potential landfill disposal.
- Based on the results of the investigation and the understood source of the metals contamination (i.e., air pollution from ore roasting), metals concentrations are expected to be highly variable across the site.
- The current sample density is not adequate to fully characterize the Subject Site given that pockets of surface soil across the site are interspersed with bedrock outcroppings.
- Additional sampling on a tighter sampling grid (7–10 m) in the soil pockets would increase confidence in contamination presence and delineation.

Figures 1-6 from the Phase II/III ESA are provided for reference.

2.4 Preliminary quantitative risk assessment

The 2024 preliminary quantitative risk assessment (PQRA) was completed by Steer Environmental Associates Ltd. (Steer). The PQRA used soil data from the Phase II/III ESA in its risk calculations. The PQRA determined that arsenic in soil posed an unacceptable health risk to residents of a future university and to regular toddler (<5 years old) patrons of a university daycare. Contaminants in soil did not pose an unacceptable risk to non-resident university students, faculty, or staff, or to children (>5 years old) as full-time university daycare patrons. The PQRA concluded there was a high likelihood that human health risks were overestimated. It also identified a potential ecological risk, but with a moderate to high uncertainty, that likely overestimated the risk.

2.5 Contaminant Characteristics and Migration

The contaminants of concern identified in the Phase II/III ESA were elevated concentrations of various metals in soils:

- Background concentrations of most metals are naturally present in soil. Many metals ions are essential for the normal functioning of most plants and animals, including humans.
- Elevated concentrations of metals can cause toxicity to plants and animals. Highly elevated concentrations of metals can be carcinogenic (i.e., cancer causing) to humans.
- The transport mechanisms for metals-contaminated soil to affect humans would be through dermal contact, ingestion, or dust inhalation.

3 REGULATORY FRAMEWORK

3.1 Applicable Guidelines

The EGCSR (GNWT 2003) was used for comparing soil analytical results and interpreting environmental risk. The EGCSR considers human and ecological exposure pathways and is a conservative first step in defining soil-based contamination. The EGCSR also considers the current and intended land uses of a site and the adjacent land uses, along with soil particle size.

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GNWT does not have guidelines specific to surface water or groundwater quality; therefore, the Canadian Council of Ministers of the Environment Canadian Water Quality Guidelines for the Protection of Aquatic Life (CCME AL) were considered (CCME 2023).

3.2 Land Use, Soil Grain Size, and Exposure Pathways

As the Subject Site is proposed to be redeveloped into a polytechnic university, residential/parkland (RL/PL) land use criteria apply. Guideline values for some parameters also depend on grain size (coarse or fine) and are categorized by depth (surface and subsoil). Determination of soil grain size is based on the soils observed during soil sampling and laboratory particle size analysis. In accordance with the EGCSR, the American Society for Testing and Materials defines fine-grained soil as having a median grain size of less than or equal to 75 µm and coarse-grained soil as that with a median grain size of greater than 75 µm (ASTM 2017). The EGCSR considers surface soils to be from the ground surface to 1.5 mbgs and subsoils to be at depths greater than 1.5 mbgs. Only surface soils were sampled for the Phase II ESA.

The exposure pathways considered in developing the appropriate guidelines for the protection of environmental and human health include:

- Ingestion and dermal contact of soils;
- Vapour inhalation (indoor);
- Protection of potable groundwater;
- Protection of groundwater for aquatic life;
- Nutrient cycling; and
- Ecological soil contact.

The most stringent pathway for the land use was applied.

Based on the naturally elevated arsenic levels in Yellowknife-area soils, the EGCSR has established a remediation objective for arsenic concentrations based on land use. The remediation objective for RL (160 mg/kg) was applied and replaces the default EGCSR value for arsenic of 12 mg/kg.

3.3 Draft Environmental Guideline for Contaminated Site Remediation

In May 2023, GNWT updated the 2003 EGCSR and released a draft edition (GNWT 2023). Although the draft EGCSR is still under review and not yet finalized, the guidelines in the soil criteria tables for RL were also considered for the Phase II ESA.

The draft EGCSR also contains proposed remediation soil quality criteria for arsenic with updated soil quality guidelines. The draft EGCSR RL/PL ambient background arsenic soil concentration for Yellowknife A (120 mg/kg) was applied for the Subject Site.

3.4 Waste Discharge Guidelines

To support the ROA, toxicity characteristic leaching procedure (TCLP) analysis was completed to determine whether metals-contaminated soil was suitable for landfill disposal. Thus, Schedule IV (Standards for Solid Waste/Process Residuals Suitable for Landfill) of the Guideline for Industrial Waste Discharges in the NWT (GNWT 2004) was used to evaluate the TCLP analytical results.

4 REMEDIAL OPTIONS ANALYSIS

The polytechnic university facilities master plan (FMP) provided the potential development footprint for a new campus in Yellowknife (GNWT 2022). One of the key criteria for selecting Tin Can Hill as a potential campus site was its natural setting, and preserving the natural environment was one of the key principles for site planning. However, the FMP is largely a conceptual document, and details such as proposed construction techniques were not included. Therefore, this ROA makes no assumptions related to the movement soil involved with campus construction. If construction techniques, such as blasting or other methods that involve moving soil, are required to complete building construction, the ROA conclusions should be reassessed.

Based on the PQRA, the proposed residences, toddler daycare facilities, and outdoor gathering areas were identified as sensitive areas, where residents and daycare patrons would be exposed to potentially contaminated soil. The daycare footprint was conservatively assumed to include the entire student services building. These sensitive areas were assumed to be 12,000 m^2 for the residences and their respective outdoor gathering areas, 2,800 m^2 for the daycare, and 2,330 m^2 for the outdoor gathering areas located southeast of the daycare (Figure 7).

At a minimum, before any campus construction can begin, the PQRA must be updated to adequately address human health risks. The current gaps for human health protection are:

- The PQRA does not consider the consumption of natural vegetation.
- The PQRA recommends additional soil sampling along the OMR that crosses the campus footprint.

The following remedial options were considered for the Subject Site. Estimates for contractor services, including removing contaminated soil and importing clean fill, were provided by KBL Environmental.

4.1 Do Not Construct Residences or Toddler Daycare

Do not remediate, and do not construct on-site residences or a toddler daycare.

- Unacceptable risks were calculated to be present only for university residents or toddler daycare patrons.
- The FMP listed daycare and housing as optional campus facilities.
- This option would remove the only unacceptable human health risks that were identified in the PQRA.
- Development could proceed with minimal additional environmental investigation to address the current gaps for human health protection in the PQRA.

This option would require collection of 20 additional soil samples of the OMR and analysis for metals, as well as sampling of any edible vegetation to provide sufficient data to address the current data gaps related to assessing human health risk. The findings can be presented in a simple addendum to the PQRA.

A summary of considerations for this method is provided in Table 4-1.

Table 4-1
No Residences or Toddler Daycare

Method summary and implementation	Do not construct residences or toddler daycare Minimal additional sampling required
Time frame	One field season for sampling
Limitations	Results may not be adequate to fully support risk assessment
Process-specific health and safety considerations	Site-specific health and safety plan for field workers
Confirmatory methods	Favourable risk assessment
Process end wastes	None
Local capacity?	Yes

Advantages/Disadvantages

The advantages of this option are:

- No additional remediation is required to start construction.
- Minimal additional sampling is required for preparing an addendum to the PQRA.
- A smaller development footprint would preserve more forest.
- Minimal carbon footprint and health and safety risks exist related to the additional work.

The disadvantages of this option are:

- Less campus facilities (i.e., no on-site residences or toddler daycare) may make the campus less attractive to potential students.
- Potential additional strain may result on the existing housing and daycare facilities.

Cost Estimate

The estimated cost to complete additional sampling for preparing a PQRA addendum is $29,700, which includes environmental consultant costs and a 10% contingency (Table 4-2).

Assumptions in developing this cost estimate include:

- The sampling results to prepare the addendum to the PQRA are favourable.
- Without the presence of residents or toddler daycare patrons, the outdoor gathering areas would not pose an unacceptable risk.

Table 4-2
Cost of Additional Sampling to Support Risk Assessment

Task	Cost
Field visit for sampling and reporting	$22,000
Risk assessment reporting	$5,000
Total (including 10% contingency)	$29,700

Summary

This option would involve limited additional investigation but would reduce campus facilities. Less development on the property means more existing natural environment would remain untouched, a guiding principle of the FMP. The FMP lists daycare and housing as optional facilities but also states that most students will be travelling from remote communities, and many will bring their families. If daycare and housing are deemed not essential campus facilities, this remedial option is recommended.

4.2 Conduct Additional Soil Sampling to Support Risk Assessment

Conduct additional intensive soil sampling at the proposed locations of residences, the toddler daycare, and outdoor gathering areas to support a risk assessment:

- The current risk assessment is based on data from a soil samples located approximately 50 m apart, that only broadly characterizes the metals concentrations across the site.
- Collecting approximately 20 additional samples (roughly 10 m grid) in each sensitive development area (decision area) would provide a defensible amount of data to estimate the risks for each area.
- Decision areas are defined as a four-unit residence with a central outdoor gathering area (the FMP proposes eight of these), the toddler daycare, and proposed outdoor gathering areas (the FMP includes two) southeast of the daycare.
- Taking 20 additional soil samples from the OMR and analyzing them for metals and sampling of any edible vegetation would also be required to address the human health risks identified in the PQRA.

Samples would be analyzed for metals, to better define the contamination concentrations and extents. These additional sample results would be used to prepare an addendum to the PQRA. The data would be added to the PQRA to better determine whether unacceptable risks are actually present in each decision area. better determining the contamination extents and More data will increase the confidence of the current risk assessment, which likely overestimates the human health risks.

A summary of considerations for this method is provided in Table 4-3.

Table 4-3
Additional Soil Sampling to Support Risk Assessment

Method summary and implementation	Additional sampling to support risk assessment
Time frame	One field season for sampling
Limitations	Results may not be adequate to fully support risk assessment
Process-specific health and safety considerations	Site-specific health and safety plan for field workers
Confirmatory methods	Favourable risk assessment
Process end wastes	None
Local capacity?	Yes

Advantages/Disadvantages

The advantages of this option are:

- If the results are favourable, no additional remediation is required.
- The natural setting of the property is maintained.
- If the results are not favourable, they would still provide a better understanding of the contamination extents for other remedial options or alternative building locations.
- No heavy machinery, equipment, or soil hauling is required.
- It is the least expensive option for pursuing the proposed development plan.

The disadvantages of this option are:

- The results may not be adequate to fully support the risk assessment.
- Another season may be required for sampling before development decisions could be made.

Cost Estimate

The estimated cost to complete intensive additional soil sampling at the proposed residences, toddler daycare and outdoor gathering areas is $59,950, which includes environmental consultant costs and a 10% contingency (Table 4-4).

Assumptions in developing this cost estimate include:

- Soil sampling is required at the footprints of all residences, outdoor gathering areas, and the toddler daycare (approximately 17,150 m^2).
- Sufficient soil exists at each location to collect samples.
- Approximately 20 soil samples would be collected from the OMR and approximately 200 soil samples would be collected from the sensitive development areas.
- No other contaminant sources are encountered.

Table 4-4
Cost of Additional Soil Sampling to Support Risk Assessment

Task	Cost
Field visit for soil sampling and reporting	$47,000
Risk assessment reporting	$7,500
Total (including 10% contingency)	$59,950

Summary

One of the guiding principles of the FMP is that the existing natural environment should remain as part of campus development, and that existing vegetation should be maintained, where possible. Given this tenet and that the PQRA has likely overestimated the human health risks, this option is recommended if residences and a daycare are essential for the campus. There is no guarantee that the findings of the additional investigation will favourably support the risk assessment. Unfavourable results that do not support the risk assessment would still provide a better understanding of the contamination extents. These results could be used to support other remedial options, such as capping or soil removal.

4.3 Cap Proposed Residence, Daycare, and Outdoor Gathering Locations

Cap the proposed locations of residences, outdoor gathering areas, and the toddler daycare with 1 m of clean fill (approximately 17,150 m^3).

- Clean fill would be imported from a local source that is not metals contaminated.
- Taking 20 additional soil samples from the OMR and analyzing them for metals, and sampling of any edible vegetation would also be required to address the human health risks identified in the PQRA.

The risk assessment identified unacceptable human health risks for campus residents and toddler daycare patrons based on potential exposure to metals-contaminated soil. The potential exposure pathways are dermal contact, ingestion, and dust inhalation. Capping these sensitive areas with 1 m of clean fill or engineered soil would remove these exposure pathways and mitigate the potential human health risks.

A summary of considerations for this method is provided in Table 4-5.

Table 4-5
Capping of Proposed Sensitive Development Areas

Method summary and implementation	Import clean fill (i.e., soil with no contamination)
Time frame	One field season for sampling and capping
Limitations	Access to proposed development areas may not be possible until roads are constructed
Process-specific health and safety considerations	Working around heavy equipment and trucks
Confirmatory methods	Capping is completed
Process end wastes	Operational carbon emissions
Local capacity?	Yes

Advantages/Disadvantages

The advantages of this option are:

- Minimal additional contamination investigation is required (OMR and vegetation sampling only).
- Fill may also be required for contouring to support building construction, given the unevenness of the bedrock. Thus, capping could serve a dual purpose in the construction.
- Less trees will be removed.

The disadvantages of this option are:

- A large volume of non-native soil must be imported.
- A large amount of heavy truck traffic will be directed through residential areas.
- It is likely overly protective as the current soil data are based on a roughly 50 m grid.
- Will create a less natural setting.
- It is expensive.
- The carbon footprint and health and safety risks are elevated due to equipment and trucking vehicle emissions.

Cost Estimate

The estimated cost to import clean fill and cap the sensitive development areas is $960,750 which includes environmental consultant costs and a 25% contingency (Table 4-6). The 25% contingency is due to the higher uncertainties for this option.

Assumptions in developing this cost estimate include:

- Capping is required over the footprints of all residences, outdoor gathering areas, and the toddler daycare (approximately 17,150 m^2).
- Approximately 34,300 tonnes of soil would be required for 1 m capping.
- Intensive soil sampling is not required to confirm that the imported fill is clean.
- Arsenic concentrations in fill are assumed to meet background residential levels.
- Residential roads can withstand the heavy truck traffic.
- Access roads will be created to reach the sensitive areas and these costs are not included as part of the remedial option estimate.

Table 4-6
Cost of Capping Sensitive Areas With Clean Fill

Task	Cost
Importing clean fill	$610,600
Spreading clean fill	$100,000
Field visits for soil sampling, fill import and spreading, and reporting.	$53,000
Risk assessment reporting	$5,000
Total (including 25% contingency)	$960,750

Summary

This option involves importing clean fill to provide a protective barrier to remove the exposure pathway for campus residents or toddler daycare patrons. Capping would occur at the residential, daycare, and outdoor gathering areas. Based on the high likelihood that human health risks were overestimated, this option is likely overly conservative. This option would involve importing a large volume of non-native soil and directing hundreds of loads of heavy truck traffic through residential areas. Therefore, this remedial option is not recommended.

A potential alternative option that may save costs is capping with 30 cm of clean fill (approximately 5,145 m^3) underlain by a geotextile liner (i.e., engineered soil). This option could be further evaluated if desired.

4.4 Remove Contaminated Soil

Remove contaminated soils from the sensitive development areas and dispose of it off site.

- All contaminated soil in the footprint of the sensitive areas would be removed.
- The contaminated soil would be disposed of at a registered disposal facility.
- Clean backfill soil would replace the removed soil.
- Taking 20 additional soil samples from the OMR and analyzing them for metals and sampling of any edible vegetation would also be required to address the human health risks identified in the PQRA.

This remedial option would remove the contaminated soils from the sensitive areas in the development footprint down to bedrock. Soil would be hauled off site to an approved disposal facility. Based on the available data, metals contamination exists in the surface soil but is only broadly delineated laterally (rough 50 m grid) and is not delineated vertically at any location. Soil is only sporadically located across the bedrock outcrops of the development footprint. Based on the limited information, the estimated volume of contaminated soil in the sensitive areas is 2,580 m^3.

Due to the bedrock terrain, traditional remediation techniques (i.e., using an excavator) are not feasible. Physical remediation of contaminated soil down to bedrock may be possible with clearing of trees and other vegetation, followed by removing the soil using a hydrovac truck.

However, there are significant logistical challenges to removing the contaminated soil from the development area:

- Vehicular access is limited to the single roadway, and off-road truck access is not possible due to the bedrock slopes.

- Some sensitive areas are up to approximately 300 m away from the road, and the maximum effective range of a truck vacuum is typically only 180 m (600 ft.).
- A dry vacuum may be able to remove some of the contaminated soil, but in any clayey or compacted areas, a crew of labourers would need to break up the soil first.
- A high-pressure water wand could be used to break up soil, but then the generated slurry would also need to be disposed of off site. Disposing of slurry is much more expensive than disposing of dry soil.
- The capacity of a hydrovac truck is roughly 10 m^3, requiring approximately 260 loads.
- Excavated areas would likely also need to be backfilled with clean imported fill.

A summary of considerations for this method is provided in Table 4-7.

Table 4-7
Removing Contaminated Soil

Method summary and implementation	Removal of contaminated soils from sensitive development areas and disposal at an approved facility
Time frame	One field season for remediation and sampling
Limitations	Traditional excavation is not possible due to presence of bedrock Limited access for hydrovac trucks Soil removal will be labour-intensive Some areas are beyond the effective range of hydrovac trucks
Process-specific health and safety considerations	Working around heavy equipment Potential human health exposure
Confirmatory methods	Remove soil to bedrock, excavation soil samples required to confirm remediation elsewhere
Process end wastes	Operational carbon emissions
Local capacity?	Yes

Advantages/Disadvantages

The advantages of this option are:

- It removes the contaminated soil in sensitive areas.
- No limitations on development exist in successfully remediated areas.

The disadvantages of this option are:

- The total waste volume and costs are highly uncertain.
- It is logistically challenging, labour-intensive, and time-consuming.
- Other than manual labour, it is unclear how locations beyond the remote hose range would be remediated.
- Additional sampling would be required to confirm that remediation was successful.
- Risk assessment and/or capping may still be required in areas that cannot effectively be remediated.
- Removal of vegetation, trees, and soils does not reflect the guidelines of the FMP.
- A large volume of non-native soil must be imported.
- A large amount of heavy truck traffic would be directed through residential areas;

- The carbon footprint and health and safety risks are elevated due to equipment and trucking vehicle emissions; and
- It is expensive.

Cost Estimate

The estimated cost to remove contaminated soils from the sensitive development areas and dispose of it off site is $1,035,000, which includes environmental consultant costs and a 25% contingency (Table 4-8). The 25% contingency is due to the increased uncertainties of this option.

The Yellowknife landfill accepts “clean fill” at no charge. The largest portion of the cost for this option is the soil disposal fee with KBL ($525,000). If the Yellowknife landfill would accept any of the contaminated soil, then there could be significant cost reductions.

Assumptions in developing this cost estimate include:

- Contaminated soil must be removed from the footprints of all residences, outdoor gathering areas, and the toddler daycare (approximately 17,150 m^2).
- Based on a 15% soil coverage over the sensitive development areas and 0.5 m soil depth, the estimated volume of soil is 1,300 m^3. This volume of metals-contaminated soil would need to be disposed of at an approved facility.
- No other contaminant sources are encountered that will require different handing, hauling, and/or remediation.
- Confirmatory soil sampling is not required as soil will be removed down to bedrock which is approximately 0.5 m below surface.
- Access roads will be created to reach the sensitive areas and these costs are not included as part of the remedial option estimate.
- There is local capacity to provide equipment and labour.
- An environmental consultant will be on site throughout the entire remediation process.
- A local receiving facility has the capacity to accept the waste.
- Arsenic concentrations in fill are assumed to meet background residential levels.

Table 4-8
Cost of Removing Contaminated Soil

Task	Cost
Soil excavation	$135,000
Soil disposal fees	$525,000
Soil backfill	$108,000
Field visits for remediation, backfill, and risk assessment soil sampling	$55,000
Risk assessment reporting	$5,000
Total (including 25% contingency)	$1,035,000

Summary

Metals contamination exists in the surface soil but is only broadly delineated laterally (rough 50 m grid) and is not delineated vertically at any location. Based on these limited data, the entire footprint for each sensitive development area is assumed to have metals-contaminated soil. Due to the bedrock terrain, traditional remediation techniques (i.e., using an excavator) are not feasible. Without constructing additional roads, remediation by hydrovac truck is possible only in limited portions of the sensitive areas identified in the PQRA. This remedial option would be labour-intensive, time-consuming, and expensive. Alternative remediation solutions may still be required in areas where remediation is not successful or possible. Removing vegetation or native soils, or importing non-native soils contradicts the guidelines of the FMP. Therefore, this remedial option is not recommended.

Note that blasting was required to create a level foundation for constructing the water treatment plant at the north end of Tin Can Hill. If similar construction techniques are required for the residences and daycare facilities, the disposal of the associated rubble could also effectively remove any contaminated surface soil in those development areas. This option could be further evaluated if applicable to the future development plans.

4.5 Summary

Table 4-9 summarizes all remedial options and costs.

Table 4-9
Comparison of Remedial Options

Option	Method Summary	Scope	Time Frame	Cost	Local Capacity	Greenhouse Gas Emissions	Recommended?
Do not construct residences or toddler daycare	This option would involve limited additional investigation but would reduce campus facilities. Less development at the property means more existing natural environment would remain untouched, a guiding principle of the FMP. The FMP lists daycare and housing as optional facilities but also states that most students will be travelling from remote communities, and many will bring their families.	• Limited environmental sampling in the proposed campus footprint to support a PQRA addendum	1 year	$30,000	Yes	Low	Yes
Conduct additional soil sampling to support risk assessment	This option would include the limited additional sampling to update the PQRA but also intensive additional sampling at the sensitive development areas. One of the guiding principles of the FMP is that the existing natural environment should remain as part of campus development and that existing vegetation should be maintained, where possible. The PQRA has likely overestimated the human health risks. There is no guarantee that the findings of the additional investigation will favourably support the risk assessment. Unfavourable results that do not support risk assessment would still provide a better understanding of the contamination extents. These results could be used to support other remedial options, such as capping or soil removal.	• Intensive soil sampling at sensitive areas to update the PQRA • Limited environmental sampling in the proposed campus footprint to support a PQRA addendum	1 year	$60,000	Yes	Low	Yes
Cap sensitive development areas	This option involves importing clean fill to provide a protective barrier to remove the exposure pathway for campus residents or toddler daycare patrons. Capping would occur at the residential, daycare, and outdoor gathering areas. Based on the high likelihood that human health risks were overestimated, this option is likely overly conservative. This option would involve importing a large volume of non-native soil and directing hundreds of loads of heavy truck traffic through residential areas.	• Importing 1 m of clean fill to cap the sensitive development areas • Limited environmental sampling in the proposed campus footprint to support a PQRA addendum	1 year	$960,750	Yes	High	No
Remove contaminated soil from sensitive development areas	This option involves removal of the contaminated soils from the sensitive development areas. Metals contamination exists in the surface soil but is only broadly delineated laterally (rough 50 m grid) and is not delineated vertically at any location. Based on these limited data, the entire footprint for each sensitive area is assumed to have metals-contaminated soil. Due to the bedrock terrain, traditional remediation techniques (i.e., using an excavator) are not feasible. Without constructing additional roads, remediation by hydrovac truck is possible only in limited portions of the sensitive areas identified in the PQRA. This remedial option would be labour-intensive, time-consuming, and expensive. Other remediation solutions may still be required in areas where remediation is not successful or possible. Removing vegetation or native soils, or importing non-native soils contradicts the guidelines of the FMP.	• Removing all potentially contaminated soil in the sensitive development areas • Limited environmental sampling in the proposed campus footprint to support a PQRA addendum	1 year	$1,035,000	Yes	High	No

5 RECOMMENDATIONS

One of the guiding principles of the FMP is that the existing natural environment should remain as part of campus development and that existing vegetation should be maintained, where possible. Given this tenet, and as the PQRA has likely overestimated the human health risks at the Subject Site, additional sampling to update the PQRA to address human health risks is the recommended option. Intensive sampling in specific development areas to refine the risk assessment is required before residences and a toddler daycare could be constructed. If these facilities are excluded in the development plans, then only environmental sampling of the OMR and any edible vegetation is required to update the PQRA before construction can proceed.

The estimated costs for recommended options in chronological order are summarized in Table 5-1.

Table 5-1
Cost Estimate for Recommended Options

	Task	Cost
1 – Do not construct residences or toddler daycare	Limited sampling to update PQRA: Field visit for sampling and reporting - $22,000 Risk assessment reporting - $5,000 10% contingency - $2,700	$29,700
2 – Refine risk assessment to support residences and toddler daycare	Conduct intensive sampling to update PQRA: Field visit for sampling and reporting - $47,000 Risk assessment reporting - $7,500 10% contingency - $5,450	$59,950

CLOSURE

This remedial options analysis was prepared for GNWT to provide an evaluation of available remedial options for the proposed campus development at Tin Can Hill based on the results and conclusions from Associated's Phase II/III ESA and Steer's PQRA.

The services provided by Associated Environmental Consultants Inc. in the preparation of this report were conducted in a manner consistent with the level of skill ordinarily exercised by members of the profession currently practising under similar conditions. No other warranty expressed or implied is made.

Respectfully submitted,
Associated Environmental Consultants Inc.

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May 8/24
NT/NU

David Parbery, M.Sc., MNRM, P.Geo. (NAPEG)
NAPEG Representative and Senior Reviewer

PERMIT TO PRACTICE
ASSOCIATED ENVIRONMENTAL CONSULTANTS INC.
Signature
Date May 8, 2024
PERMIT NUMBER: P 1084
NT/NU Association of Professional Engineers and Geoscientists

Permit to Practice
Associated Environmental Consultants Inc.

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Northern Environment
Unit 201, 5103 48 Street
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ASSOCIATED ENVIRONMENTAL CONSULTANTS INC.

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Subject to the following conditions and limitations, the investigation described in this report has been conducted by Associated Environmental Consultants Inc. (Associated) for the Government of Northwest Territories (the Client) in a manner consistent with a reasonable level of care and skill normally exercised by members of the environmental science profession currently practicing under similar conditions in the area.

1. The scope of the investigation described in this report has been limited by the budget set for the investigation in the work program. The scope of the investigation has been reasonable having regard to that budget constraint.
2. The investigation described in this report has been limited to the scope of work described in the work program.
3. The investigation described in this report has relied upon information provided by third parties concerning the history of the site. Except as stated in this report, we have not made an independent verification of such historical information.
4. The investigation described in this report has been made in the context of existing government regulations generally promulgated at the date of this report. Except as specifically noted, the investigation did not take account of any government regulations not in effect and generally promulgated at the date of this report.
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6. The findings and conclusions are valid only for the specific site identified in the report.
7. Since site conditions may change over time, the report is intended for immediate use.
8. This report is intended for the exclusive use of the Client, including all successors and assigns. The material in it reflects Associated's best judgement, in light of the information available to it, at the time of preparation. Any use that a third party makes of this report, or any reliance on or decisions to be made based on it, are the responsibility of such third parties. Associated accepts no responsibility for damages, if any, suffered by any third party as a result of decisions made or actions based on this report and makes no representation of fact or opinion of any nature whatsoever to any person or entity other than the Client.

In accepting delivery of this report, the Client hereby agrees that:

A. Associated's liability for all claims of the Client, arising out of the agreement between Associated and the Client, pursuant to which this report has been prepared (the Agreement) shall absolutely cease to exist after a period of six (6) years from the date of:

    i. substantial completion of the investigation described in this report,
    ii. termination of Associated's Services under the Agreement,
    iii. commencement of the limitation period for claims prescribed by any statute of the Province or Territory for the site of the investigation described in this report,
    iv. any significant alteration of the site of the investigation described in this report, and/or neighbouring properties after the date of the final report that would change the conclusions and recommendations of the final report,

    whichever shall first occur, and following the expiration of such period, the Client shall have no claim whatsoever against Associated.

B. Any and all claims that it may have against Associated's or any of its servants, agents, or employees arising out of or in any way connected with the investigation described in this report or the preparation of this report, whether such claims are in contract or in tort, and whether such claims are based on negligence or otherwise, shall be limited to a total amount equal to the fees payable to Associated's under the contract with the Client. Associated's shall bear no liability whatsoever for any consequential loss, injury or damage incurred by the Client including but not limited to claims for loss of profits and loss of markets.

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Associated Environmental Consultants Inc. (Associated). 2023. Advanced Phase I Environmental Site Assessment, Tin Can Hill, Yellowknife, NT. Prepared for the Government of Northwest Territories.

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APPENDIX A – FIGURES

ALTHOUGH ASSOCIATED HAS TAKEN THE EFFORT AND DUE CARE TO ENSURE THE ACCURACY OF THE INFORMATION DISPLAYED AT THE DATE OF PRODUCTION, THE USER ACKNOWLEDGES THAT CHANGES OVER TIME AND THE CURRENCY OF THE DATASET(S) MAY IMPACT THE ACCURACY OF THE INFORMATION WITHOUT NOTICE. ASSOCIATED SHALL NOT BE HELD LIABLE TOWARDS THE RESULTS OBTAINED FROM THE USE OF THIS INFORMATION. SCALE(S) SHOWN ARE INTENDED FOR LETTER (8.5X11) SIZE ONLY.

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Associated Environmental

AE PROJECT NO.	2023-8451
SCALE	1:100,000
COORD. SYSTEM	NAD 1983 UTM ZONE 11N
DATE	2023-12-15
REV	00
DRAWN BY	BDJ
CHECKED BY	TR

FIGURE 1: SITE LOCATION PLAN

GOVERNMENT OF NORTHWEST TERRITORIES

REMEDIAL OPTIONS ANALYSIS – TIN CAN HILL, YELLOWKNIFE, NT

ALTHOUGH ASSOCIATED HAS TAKEN THE EFFORT AND DUE CARE TO ENSURE THE ACCURACY OF THE INFORMATION DISPLAYED AT THE DATE OF PRODUCTION, THE USER ACKNOWLEDGES THAT CHANGES OVER TIME AND THE CURRENCY OF THE DATASET(S) MAY IMPACT THE ACCURACY OF THE INFORMATION WITHOUT NOTICE. ASSOCIATED SHALL NOT BE HELD LIABLE TOWARDS THE RESULTS OBTAINED FROM THE USE OF THIS INFORMATION. SCALE(S) SHOWN ARE INTENDED FOR LETTER (8.5X11) SIZE ONLY.

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- Test Pit - Peat
- Test Pit - Sand & Gravel
- Test Pit - Silt
- Test Pit - Silt / Peat
- Surface Water Sample
- Proposed Sampling Point - No Soil
- Proposed Sampling Point - No Surface Water
- Subject Property
- Parcel Boundary

AE PROJECT NO.	2023-8451
SCALE	1:3,800
COORD. SYSTEM	NAD 1983 UTM ZONE 11N
DATE	2023-12-18
REV	00
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FIGURE 2: SAMPLING LOCATION PLAN

GOVERNMENT OF NORTHWEST TERRITORIES

REMEDIAL OPTIONS ANALYSIS – TIN CAN HILL, YELLOWKNIFE, NT

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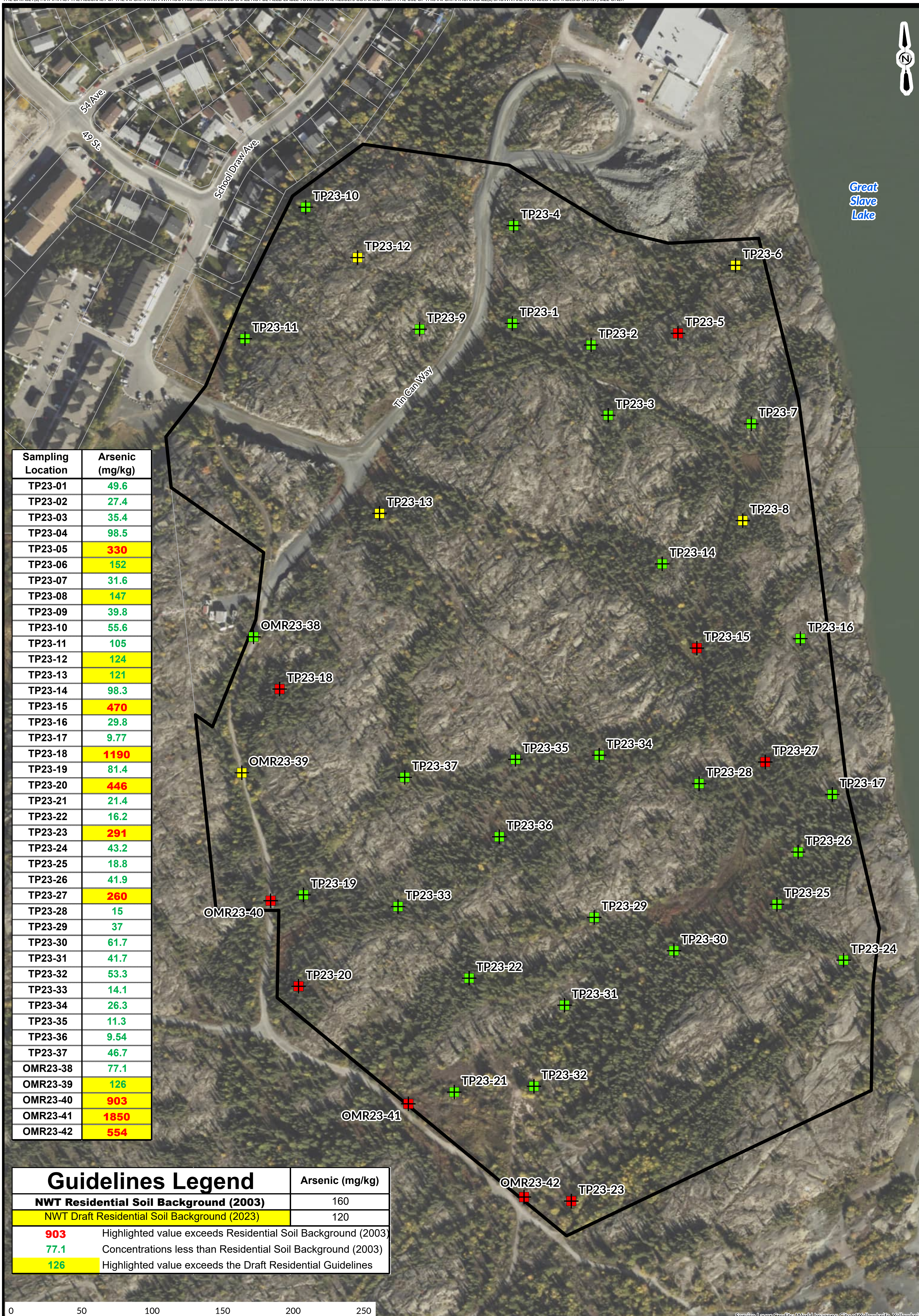

Sampling Location	Arsenic (mg/kg)
TP23-01	49.6
TP23-02	27.4
TP23-03	35.4
TP23-04	98.5
TP23-05	330
TP23-06	152
TP23-07	31.6
TP23-08	147
TP23-09	39.8
TP23-10	55.6
TP23-11	105
TP23-12	124
TP23-13	121
TP23-14	98.3
TP23-15	470
TP23-16	29.8
TP23-17	9.77
TP23-18	1190
TP23-19	81.4
TP23-20	446
TP23-21	21.4
TP23-22	16.2
TP23-23	291
TP23-24	43.2
TP23-25	18.8
TP23-26	41.9
TP23-27	260
TP23-28	15
TP23-29	37
TP23-30	61.7
TP23-31	41.7
TP23-32	53.3
TP23-33	14.1
TP23-34	26.3
TP23-35	11.3
TP23-36	9.54
TP23-37	46.7
OMR23-38	77.1
OMR23-39	126
OMR23-40	903
OMR23-41	1850
OMR23-42	554

Guidelines Legend	Arsenic (mg/kg)
NWT Residential Soil Background (2003)	160
NWT Draft Residential Soil Background (2023)	120

903	Highlighted value exceeds Residential Soil Background (2003)
77.1	Concentrations less than Residential Soil Background (2003)
126	Highlighted value exceeds the Draft Residential Guidelines

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Associated Environmental

Subject Property
Parcel Boundary

Test Pits

- Concentrations less than Residential Soil Background (2003)
- Exceeds the Draft Residential Guidelines
- Exceeds Residential Soil Background (2003) and the Draft Residential Guidelines

AE PROJECT NO.	2023-8451
SCALE	1:2,500
COORD. SYSTEM	NAD 1983 UTM ZONE 11N
DATE	2023-12-15
REV	00
DRAWN BY	BDJ
CHECKED BY	TR

FIGURE 3: SOIL ANALYTICAL RESULTS – ARSENIC

GOVERNMENT OF NORTHWEST TERRITORIES

REMEDIAL OPTIONS ANALYSIS – TIN CAN HILL, YELLOWKNIFE, NT

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Guidelines Legend	Antimony	Barium	Cobalt	Copper	Selenium	Vanadium	Zinc
NWT Tier 1 RL/PL CS/FS	20	500	50	63	1	130	200

Northwest Territories Tier 1 Soil Remediation Guidelines for Residential/ Parkland Land Use for coarse-grained and fine-grained soil

903 Highlighted value exceeds NWT Tier 1 RL/PL CS/FS guidelines

77.1 Concentrations less than NWT Tier 1 RL/PL CS/FS guidelines

Units for all parameters are mg/kg

NG - no guideline

Parameter	TP23-01	TP23-02	TP23-03	TP23-04	TP23-05	TP23-06	TP23-07	TP23-08	TP23-09	TP23-10	TP23-11	TP23-12	TP23-13	TP23-14	TP23-15	TP23-16	TP23-17	TP23-18	TP23-19	TP23-20	TP23-21
Antimony	1.14	6.52	3.42	17.1	9.03	**27**	7.45	1.34	1.89	**36**	2.66	**27.4**	7.15	9.08	4.16	2.84	3.11	16.9	12.2	15.7	1.72
Barium	93.1	22.5	32.7	51.7	102	10.6	37.3	74.6	9.83	30	68.2	54.9	53.2	292	43.8	84.5	80.7	112	31	212	169
Cobalt	13.2	1.67	1.29	6.04	23.5	1.1	1.84	12.9	0.28	4.14	12.3	5.32	2.88	40.6	6.92	1.92	1.42	4.4	4.25	13.8	11
Copper	**68.8**	12.4	7.71	18.8	30.8	16	14.3	17.4	3.63	32.2	15.5	18.4	7.4	35.4	22.7	15.1	21.2	20.3	28	25.9	31.6
Selenium	0.49	<0.37	<0.38	<0.38	<0.37	<0.38	0.43	<0.37	<0.37	0.42	<0.37	<0.37	<0.30	<0.30	<0.30	0.49	**1.14**	<0.30	<0.30	<0.30	0.27
Vanadium	41	1.78	1.66	4.05	44.3	4.25	2.45	45.6	0.77	3.45	42.7	10.7	9.9	7.89	26.3	3.81	3.44	9.84	9.73	26	55.1
Zinc	40.1	5.8	4.1	20.5	76.5	16.6	16.9	30.4	8.1	25	86.6	26.3	13.7	94.7	19.2	30.9	9.7	23.4	21.2	59.7	53.6

Parameter	TP23-22	TP23-23	TP23-24	TP23-25	TP23-26	TP23-27	TP23-28	TP23-29	TP23-30	TP23-31	TP23-32	TP23-33	TP23-34	TP23-35	TP23-36	TP23-37	OMR23-38	OMR23-39	OMR23-40	OMR23-41	OMR23-42
Antimony	0.52	12	10.8	3.83	3.93	14.8	6.91	12.4	9.19	14	10.8	1.62	1.69	4.92	3.7	12.1	0.86	1.16	3.17	3.56	6.04
Barium	192	**2770**	51.3	71.3	126	81.3	59.2	42.5	77.9	46.8	79.1	172	91.4	172	98	50.4	39.6	47.4	30.6	24.5	53.2
Cobalt	11	12.4	2.62	2.4	3.36	2.32	1.93	3.27	3.72	2.67	1.88	5.86	2.55	2.72	1.27	2.06	8.62	9.33	12.8	19.1	12.3
Copper	22.3	35.3	18.6	13.6	25.8	8.17	**145**	**76.7**	45.6	**66.6**	23.6	41.9	33.5	**121**	50.3	15.2	21.8	26.7	44	52	32.4
Selenium	<0.20	0.31	<0.30	0.56	0.69	<0.30	**1.54**	**1.31**	**1.09**	**1.42**	0.63	**1.16**	**1.05**	**3.23**	**2.27**	0.46	<0.20	<0.20	<0.20	<0.20	<0.20
Vanadium	50.6	42.8	5.58	1.45	1.73	4.59	4.3	4.08	3.81	3.58	3.33	29.4	12.2	7.41	1.99	4.24	32.2	34	39	51.5	39.4
Zinc	50.2	**768**	60.9	33	57	49.4	60.4	28.8	26.3	83.6	68	17.1	13.7	5.2	19.1	13.4	41.4	47.8	48	49.9	50.4

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Associated Environmental

Subject Property

Parcel Boundary

Test Pits

Concentrations less than NWT Tier 1 RL/PL CS/FS guidelines

Concentrations greater than NWT Tier 1 RL/PL CS/FS guidelines

AE PROJECT NO. 2023-8451
SCALE 1:3,000
COORD. SYSTEM NAD 1983 UTM ZONE 11N
DATE 2023-12-19
REV 00
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FIGURE 4: SOIL ANALYTICAL RESULTS – OTHER METALS

GOVERNMENT OF NORTHWEST TERRITORIES

REMEDIAL OPTIONS ANALYSIS – TIN CAN HILL, YELLOWKNIFE, NT

ALTHOUGH ASSOCIATED HAS TAKEN THE EFFORT AND DUE CARE TO ENSURE THE ACCURACY OF THE INFORMATION DISPLAYED AT THE DATE OF PRODUCTION, THE USER ACKNOWLEDGES THAT CHANGES OVER TIME AND THE CURRENCY OF THE DATASET(S) MAY IMPACT THE ACCURACY OF THE INFORMATION WITHOUT NOTICE. ASSOCIATED SHALL NOT BE HELD LIABLE TOWARDS THE RESULTS OBTAINED FROM THE USE OF THIS INFORMATION. SCALE(S) SHOWN ARE INTENDED FOR TABLOID (11X17) SIZE ONLY.

Guidelines Legend	Antimony	Barium	Boron	Cobalt	Copper	Selenium	Vanadium	Zinc
2023 Draft Residential Guidelines	7.5	390	3.3	20	63	1	18	250

NWT Draft 2023 Environmental Guideline for Contaminated Site Remediation

77.1	Concentrations less than the 2023 Draft Residential Guidelines
126	Highlighted value exceeds the 2023 Draft Residential Guidelines
<5.0	Detection limit is greater than the guideline

Units for all parameters are mg/kg

Parameter	TP23-01	TP23-02	TP23-03	TP23-04	TP23-05	TP23-06	TP23-07	TP23-08	TP23-09	TP23-10	TP23-11	TP23-12	TP23-13	TP23-14	TP23-15	TP23-16	TP23-17	TP23-18	TP23-19	TP23-20	TP23-21
Antimony	1.14	6.52	3.42	17.1	9.03	27	7.45	1.34	1.89	36	2.66	27.4	7.15	9.08	4.16	2.84	3.11	16.9	12.2	15.7	1.72
Barium	93.1	22.5	32.7	51.7	102	10.6	37.3	74.6	9.83	30	68.2	54.9	53.2	292	43.8	84.5	80.7	112	31	212	169
Boron	<9.3	<9.3	<9.4	<9.4	<9.3	<9.4	<9.4	<9.4	<9.4	<9.4	<9.4	<9.4	<7.5	<7.4	<7.5	9.1	22.6	<7.5	<7.4	<7.4	8.4
Cobalt	13.2	1.67	1.29	6.04	23.5	1.1	1.84	12.9	0.28	4.14	12.3	5.32	2.88	40.6	6.92	1.92	1.42	4.4	4.25	13.8	11
Copper	68.8	12.4	7.71	18.8	30.8	16	14.3	17.4	3.63	32.2	15.5	18.4	7.4	35.4	22.7	15.1	21.2	20.3	28	25.9	31.6
Selenium	0.49	<0.37	<0.38	<0.38	<0.37	<0.38	0.43	<0.37	<0.37	0.42	<0.37	<0.37	<0.30	<0.30	<0.30	0.49	1.14	<0.30	<0.30	<0.30	0.27
Vanadium	41	1.78	1.66	4.05	44.3	4.25	2.45	45.6	0.77	3.45	42.7	10.7	9.9	7.89	26.3	3.81	3.44	9.84	9.73	26	55.1
Zinc	40.1	5.8	4.1	20.5	76.5	16.6	16.9	30.4	8.1	25	86.6	26.3	13.7	94.7	19.2	30.9	9.7	23.4	21.2	59.7	53.6

Parameter	TP23-22	TP23-23	TP23-24	TP23-25	TP23-26	TP23-27	TP23-28	TP23-29	TP23-30	TP23-31	TP23-32	TP23-33	TP23-34	TP23-35	TP23-36	TP23-37	OMR23-38	OMR23-39	OMR23-40	OMR23-41	OMR23-42
Antimony	0.52	12	10.8	3.83	3.93	14.8	6.91	12.4	9.19	14	10.8	1.62	1.69	4.92	3.7	12.1	0.86	1.16	3.17	3.56	6.04
Barium	192	2770	51.3	71.3	126	81.3	59.2	42.5	77.9	46.8	79.1	172	91.4	172	98	50.4	39.6	47.4	30.6	24.5	53.2
Boron	10.4	<7.4	8.5	10.2	13.6	<7.5	8.5	25.3	24.8	29.2	32.5	6.2	12.8	17.9	21.4	<7.4	<5.0	<5.0	<5.0	<5.0	<5.0
Cobalt	11	12.4	2.62	2.4	3.36	2.32	1.93	3.27	3.72	2.67	1.88	5.86	2.55	2.72	1.27	2.06	8.62	9.33	12.8	19.1	12.3
Copper	22.3	35.3	18.6	13.6	25.8	8.17	145	76.7	45.6	66.6	23.6	41.9	33.5	121	50.3	15.2	21.8	26.7	44	52	32.4
Selenium	<0.20	0.31	<0.30	0.56	0.69	<0.30	1.54	1.31	1.09	1.42	0.63	1.16	1.05	3.23	2.27	0.46	<0.20	<0.20	<0.20	<0.20	<0.20
Vanadium	50.6	42.8	5.58	1.45	1.73	4.59	4.3	4.08	3.81	3.58	3.33	29.4	12.2	7.41	1.99	4.24	32.2	34	39	51.5	39.4
Zinc	50.2	768	60.9	33	57	49.4	60.4	28.8	26.3	83.6	68	17.1	13.7	5.2	19.1	13.4	41.4	47.8	48	49.9	50.4

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Associated Environmental

Subject Property

Parcel Boundary

Test Pits

- Concentrations less than the 2023 Draft Residential Guidelines
- Concentrations less than the 2023 Draft Residential Guidelines and detection limit is greater than the guideline
- Concentrations greater than the 2023 Draft Residential Guidelines

AE PROJECT NO.	2023-8451
SCALE	1:3,000
COORD. SYSTEM	NAD 1983 UTM ZONE 11N
DATE	2023-12-19
REV	00
DRAWN BY	BDJ
CHECKED BY	TR

FIGURE 5: SOIL ANALYTICAL RESULTS – OTHER METALS, DRAFT GUIDELINES

GOVERNMENT OF NORTHWEST TERRITORIES

REMEDIAL OPTIONS ANALYSIS – TIN CAN HILL, YELLOWKNIFE, NT

ALTHOUGH ASSOCIATED HAS TAKEN THE EFFORT AND DUE CARE TO ENSURE THE ACCURACY OF THE INFORMATION DISPLAYED AT THE DATE OF PRODUCTION, THE USER ACKNOWLEDGES THAT CHANGES OVER TIME AND THE CURRENCY OF THE DATASET(S) MAY IMPACT THE ACCURACY OF THE INFORMATION WITHOUT NOTICE. ASSOCIATED SHALL NOT BE HELD LIABLE TOWARDS THE RESULTS OBTAINED FROM THE USE OF THIS INFORMATION. SCALE(S) SHOWN ARE INTENDED FOR TABLOID (11X17) SIZE ONLY.

Analyte	Unit	Guideline CCME AL (LT)	SW23-01	SW23-02
Lab Results				
Fluoride	mg/L	0.12	0.088	**0.228**
Total Metals				
Aluminum (total)	mg/L	0.1	0.0926	**0.783**
Arsenic (total)	mg/L	0.005	0.00248	**0.401**
Chromium (total)	mg/L	0.001	**0.0023**	**0.00414**
Copper (total)	mg/L	0.002-0.004	0.00147	**0.041**
Iron (total)	mg/L	0.3	0.127	**1.28**
Lead (total)	mg/L	0.001-0.007	0.00013	**0.00784**
Zinc (total)	mg/L	0.0017	<0.0030	**0.0224**
Dissolved Metals				
Arsenic (dissolved)	mg/L	0.005	0.00207	**0.324**

CCME AL (LT)	CCME Canadian water quality guidelines for the protection of freshwater aquatic life, Long-Term Exposure guidelines.
0.088	Concentration less than guideline
0.0023	Concentration greater than guideline
<	Less than reported detection limit
<0.0030	Highlighted value has a detection limit that is greater than standard

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Associated Environmental

Subject Property
Parcel Boundary
Water Sample Locations
Concentration less than guideline
Concentration greater than guideline

AE PROJECT NO.	2023-8451
SCALE	1:3,000
COORD. SYSTEM	NAD 1983 UTM ZONE 11N
DATE	2023-12-18
REV	00
DRAWN BY	BDJ
CHECKED BY	TR

FIGURE 6: SURFACE WATER ANALYTICAL RESULTS

GOVERNMENT OF NORTHWEST TERRITORIES

REMEDIAL OPTIONS ANALYSIS – TIN CAN HILL, YELLOWKNIFE, NT

Figure 7: Sensitive Areas

Sensitive Areas:
SW residence - 3,000 m^2
NW residence - 4,500 m^2
NE residence - 4,500 m^2
Student services building - 2,800 m^2
Central outdoor - 1,750 m^2
SE outdoor gathering area - 580 m^2

Total: ~17,150 m^2

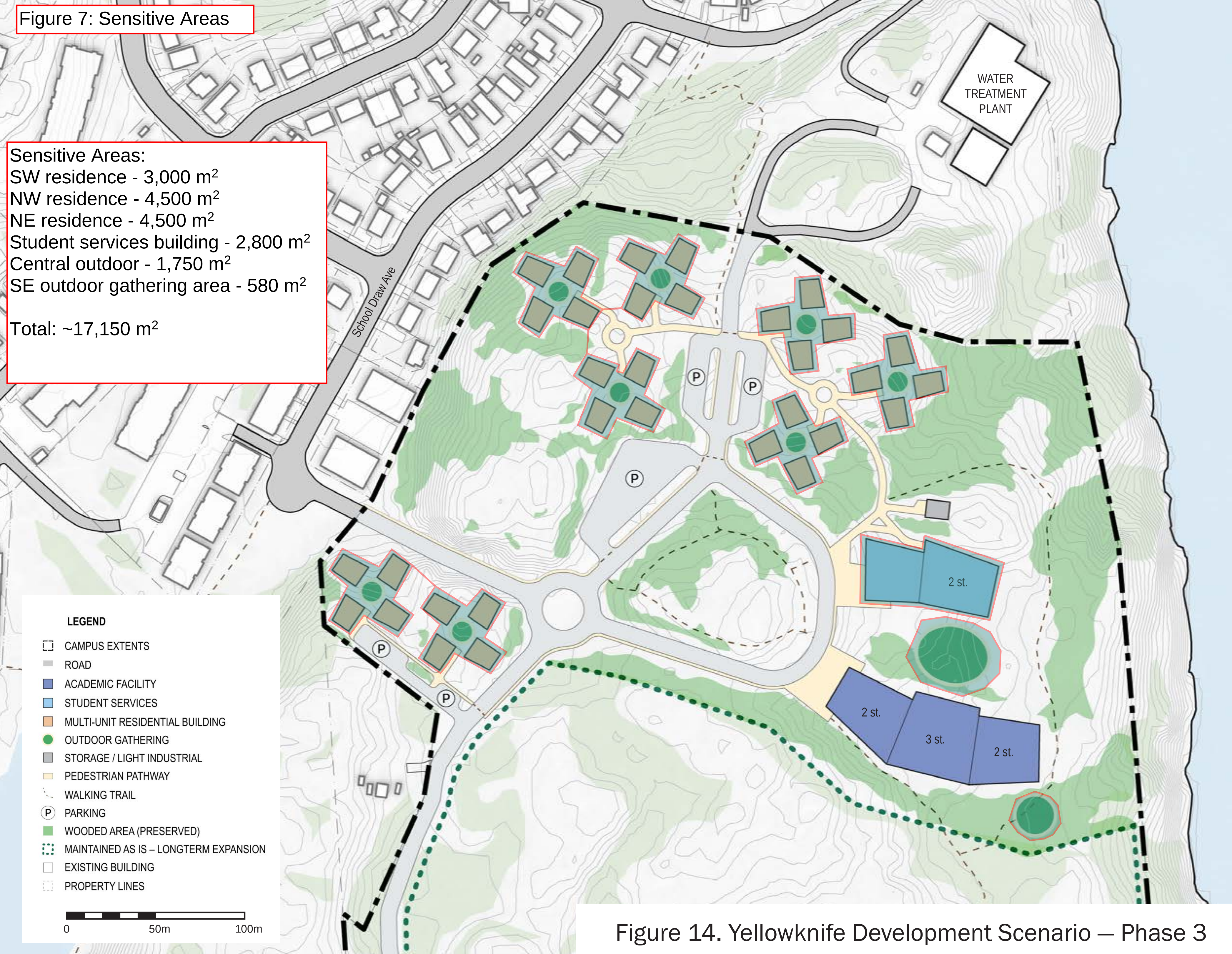

Figure 14. Yellowknife Development Scenario — Phase 3