PHC SOIL TREATMENT PLAN

CAM-E Environmental Remediation

Keith Bay, Nunavut

Presented to

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TABLE OF CONTENTS

PAGE

1. INTRODUCTION

The purpose of this document is to present the petroleum hydrocarbons (PHC) contaminated soil treatment plan elaborated for the environmental remediation of the CAM-E former DEW Line site located approximately 75 km east of Kugaaruk, as part of the Keith Bay area in Nunavut.

The remediation project was awarded to Kudlik Construction Ltd. in May 2016. In September 2016, heavy equipment, camp facilities, material and all consumables were delivered by sealift to Kugaaruk. All equipment, material and consumables required to achieve the remediation project were transported by CAT train during the winter 2017 from Kugaaruk to CAM-E.

This document is covering the procedures for the petroleum hydrocarbon contaminated (PHC) soils excavation as well as the construction, the operation and the decommissioning of the treatment facilities. The plan will be effective from July 2017 and may be updated according to the site conditions.

Figure 1: Site location

2. TYPE B PHC SOILS TREATMENT FACILITY

All type B PHC soils identified on the contractual drawings will be excavated, transported and treated into the landfarm facilities, as per described in the following sections. According to the construction drawings, a total of 1986 m^3 of type B PHC soils must be excavated within 7 different areas. After the end of the first remediation summer, almost twice of this volume was excavated.

2.1 CONSTRUCTION

2.1.1 Cell 1

The cell 1 was built at the location indicated on the drawings issued for construction. The treatment surface represents 5,814 m^2. The floor surface was regraded to promote drainage to the north-west corner. An ORPE liner was installed between two layers of geotextile on the floor surface and up to the top of the berms. A 300 mm thick sand cover was placed on the top geotextile. A layer of 400 mm of contaminated soils was placed on the entire surface with the exception of the north-east and south-west corners where rocks were stockpiled.

2.1.2 Cell 2

The Cell 2 was built directly west of the cell 1 and the west berm of the Cell 1 was used as a common berm for both cells. The treatment surface represents 4,744 m^2. The floor surface was regraded to promote drainage to the north-west corner. An HDPE liner was installed between two layers of geotextile on the floor surface and up to the top of the berms. A 400 mm thick gravel cover was placed on the top geotextile. A layer of 400 mm of contaminated soils was placed on the entire surface with the exception of the south-west corner were rocks were stockpiled.

3. TYPE B PHC SOILS EXCAVATION

The first step for the contaminated soil excavations will be to identify, stake and survey the areas to be excavated. The departmental site representatives will be invited to confirm the excavation limits before starting any works. Once the excavation areas are confirmed and staked, Kudlik will prepare the site access and any nuisance around and within an excavation area will be removed, treated and disposed of according to specifications.

As excavation work progress, when possible, boulders (200 mm and bigger) will be left in place inside the work area. Any buried debris found within the excavation limits will be verified for the presence of hazardous material and disposed of appropriately.

According to the size of the excavations, 3 types of excavators will be used for removing the contaminated soils. The Takeeuchi TB1140 will be used for smaller excavations while the Hitachi EX300-LC2 or the Hitachi 450 will be used for larger sites. The soils will be loaded into 30 tons off-road trucks (2) and transported into the treatment facility where it will be placed in a single stockpile to be screened.

Haul trucks will not circulate on impacted soil at the excavation sites or in the treatment facility. Truck boxes will be loaded in way to make sure that no soil will be falling off during the transportation. The truck leak proof tailgate must be properly closed.

Once the confirmatory soil samples will have demonstrated that no more soil with concentrations above the criteria is present in the excavation, this one will be backfilled with clean granular material. Prior to backfilling, any ponding water present in the excavation will be tested. According to the analytical results, the water will be pumped out and discharged or temporarily stored for further treatment. The same procedure will be followed in the situation where a secondary excavation would be needed.

4. TYPE B PHC SOILS PLACEMENT INTO THE LANDFARM

4.1 SOIL SCREENING

For a more efficient treatment, the excavated type B PHC soils will be screened to 63 mm in order to remove all cobbles. The coarser material will be stockpiled within the landfarm facility and once dried will be inspected for the presence of PHC stains. Stained material will be kept inside the landfarm for further processing. The clean cobble piles will be stockpiled separately outside of the landfarm facility for potential reuse on site. This will provide additional space in the case where more PHC soil would need treatment.

The type B PHC contaminated soils will be screened on a Vibroscreen SCM75 or with the excavator and the screening bucket.

As presented on the figure 2 in the Appendix 1, oversize material was placed in the corners of both facilities. At the beginning of the summer 2018, the oversize material will be removed from the landfarm and stockpiled nearby.

4.2 SOIL PLACEMENT

At the end of the first remediation season, both landfarm's cells were fully occupied with either type B soils or rock stockpiles. Areas A-4, B-4 and C-4 in the Cell 2 are free from contaminated soils but occupied with rock stockpiles. Once these stockpiles will have been removed, an area of about 357 m^2 will be available for soil treatment.

In the Cell 1, rocks were stockpiled on areas G-1, H-1, I-1, J-1 and on a small portion of A-4. However, only the area J-1 is free from soil. According to the analytical results done on soil samples collected from the Cell 1 in July / August 2017, the soil from 16 areas was meeting the treatment criteria. Additional testing will be done at the beginning of the summer 2018. If the results confirm that the soil meet the treatment criterial, it could be removed from the Cell 1 in order to leave room for additional contaminated soil.

If new contaminated soil is added into the landfarm, it will screened and placed to a maximum thickness 400 mm on the floor where room is available.

5. TYPE B PHC SOIL TREATMENT

5.1 TREATMENT OBJECTIVE

As per the contractual specifications, the contaminated soils will be considered remediated once the analytical results from the soil samples will show a total petroleum hydrocarbon (TPH) content for the fraction F1 to F3 less than 2500 mg/kg: «contaminated soil will be designated as treated soil if the results of the laboratory analytical testing of a composite sample obtained from five discrete soil sample locations representative of a 100 cubic metre soil volume indicate concentration levels of PHCs to be less that the applicable remediation criteria.»

The TPH for the type B contaminated soil will be calculated with the following method:

PHC FRACTION	SOIL TREATMENT
TYPE B= F1 (C6 to C10) + F2 (>C10 to C16) + F3 (>C16 to C34)	2500 mg/Kg

Gasoline releases fall primarily within the F1 range, with lesser amounts of F2. Diesel and heating oil composition typically spans F2 and F3. Asphaltenes and many of the residual products of heavy crude releases to soil after weathering in the environment fall within the F3 and F4 range.

Type A hydrocarbon contamination relates to the Canada Wide Standards (CWS) PHC fractions F3-F4 (i.e. heavy end products). To have a Type A contaminated soil, the sum of F3 and F4 must be greater than 70% of the total petroleum hydrocarbon (TPH) concentrations (sum of F1 to F4) and the F2 concentration should be less than the F4 concentration. During the summer 2017, most of the type A contaminated soils were excavated and disposed at the non-hazardous waste landfill (NHWL). Any remaining type A to be excavated will be also disposed at the NHWL, according to the specifications.

5.2 METHOD OF TREATMENT

5.2.1 Optimal soil characteristics for landfarming

5.2.1.1 Oxygen

Oxygen plays an important role in the bioremediation activity. Even if no consensus does exist in regard to the O_2 level for the optimal bioremediation, previous experiences suggest that the O_2 levels should be kept between 10 -15%.

As described in the previous section, the PHC contaminated soils will be screened in order to remove the cobbles. This operation is part of treatment since it contributes to bring a higher level of oxygen in soil. The tilling process, as described below, will ensure proper aeration in keeping the soil loose.

Drainage within the facility will also contribute to optimise O_2 levels in the soil. Soils saturated with water do not promote aerobic exchanges.

No instrument will be used to measure O_2 levels in the soil; regular tilling and drainage maintenance will ensure proper O_2 levels.

5.2.1.2 Soil moisture

Moisture content within the soil is an important factor to control, as it can limit the internal transport of nutrients, organic constituents and microbes in the soil matrix, influencing the bioremediation rates. According to the US26 EPA (2009b), the optimal range for soil moisture should be between 12 to 30 % by weight. In a general way, the soil should be moist, not dry and dusty or dripping wet. Moisture in treated soils will be measured and adjusted accordingly. Water collected inside the treatment facility will be used for this purpose.

5.2.1.3 Microbial population

Heterotrophs are a group of microorganisms including yeasts, molds, and bacteria that use organic carbon as their sole carbon and energy source. Many heterotrophic organisms consume carbon compounds such as sugars, alcohol, and organic acids as their food source. However, there are some specialised organisms capable of decomposing cellulose, lignin, chitin, keratin, complex hydrocarbons, phenol and other substances. Heterotrophic organisms are widely found in soil, water, food, and the bed soils of bodies of water.

To promote the biological degradation of PHC in the soil, the minimum heterotrophic plate count should be 10^3 CFU/g (colony forming units/gram). Below this minimum, landfarming may still be effective provided the existing bacteria are stimulated using nutrients or soil is amended to increase the bacteria population (USEPA. 1994.). The microbial population will be measured once the soil will have been placed into the treatment area. According to the results, nutrient maybe added to promote the microbiological activity.

Nitrogen is most often the limiting nutrient to biological degradation in cold climate. We calculated the quantities of Urea 46-0-0 (source of nitrogen) and Phosphoric acid 85% (source of P_2O_5) required providing enough nutrients to promote the bioremediation activity. The carbon content of the hydrocarbons was estimated to 9300 kg from the soil quantities and PHC concentrations data provided. A Carbon:Nitrogen:Phosphorous ratio of 100:5:1 was used to calculate the Nitrogen and Phosphorous to add.

In the case where nutrients need to be added, they will be prepared in liquid form in 1000 liters batch in a tote tank and will be spread on the contaminated soils with the help of a pump and a hose. The soils will be tilled shortly after the application.

5.2.1.4 pH

Biodegradation is greater under neutral to slightly alkaline conditions. The soil to be treated should be kept at a pH value between 6.0 and 8.0. The biodegradation activities and the addition of too much nitrogen can decrease the pH in the soils. The initial pH of the soil once placed into the treatment area will be measured. If results show the soils to be acidic or if the pH decreases below 6 during the treatment process, it will be adjusted by the addition of hydrated lime. If pH is above 8, elemental sulfur will be used.

5.2.2 Soil tilling

A Kverneland roto-tiller pulled by Challenger MT-855 tractor will be used for tilling the contaminated soils. The roto-tiller maximum depth will be adjusted to 400mm. The tilling will be started as soon as the contaminated soil will have been placed. The soil tilling will be done at least once daily until the first results of the summer 2018 become available.

5.3 SOIL SAMPLING

5.3.1 Soil sampling parameters and frequency

For the 2018 remediation season, both landfarm's cells will be sampled for petroleum hydrocarbons F1-F3 during the first week after de mobilization. According to the analytical results, treated soils will be removed and stockpiled outside of the landfarm facility. The treatment will be pursued on the untreated soils and samples will be collected each two weeks to observe the treatment progress.

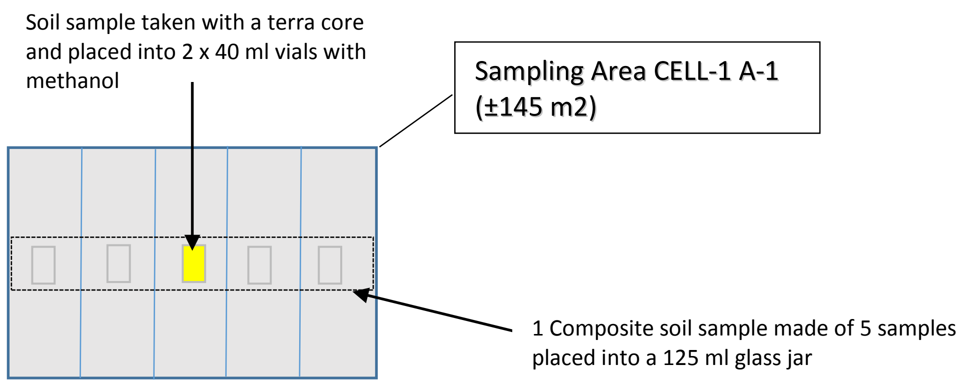
The contaminated soil in Cell 01 was sampled during the summer 2017 in order to find out if it was required to add nutrient. The results have shown that there was a bacteriological population adequate to promote the hydrocarbons degradation but the nutrient content was low. Based on these results, nutrients will be added in both cells at the beginning of the season in order to stimulate the microbiological activity. However, no additional analyses will be done in regard to the nutrient content and the bacteriological activity.

5.3.2 Soil sampling procedure

As presented on the Figure 2 in Appendix 1, each cell was divided in 40 sampling areas numbered A1-to-A4, B1-to-B4, C1-to-C4...J1-J4. Each of these areas represent about 145 m^2 or 58 m^3 of soil in Cell 1 and 119 m^2 or 48 m^3 in Cell 2.

Each landfarm sampling areas will be divided in 5 equal sub-areas that will be used to collect a composite soil sample. Each composite sample will be collected from freshly exposed soil at the center of each sub-area at a depth of 200 mm using a clean metal trowel. Each composite sample will be placed in a single Ziplok bag and mixed thoroughly. Once mixed, the composite soil sample will be placed in a 125 ml glass jar and packed in order to leave minimal air space. In addition, two soil samples will be collected in the center of the sampling area with a Terra Core and placed into two vials containing methanol.

All soil containers will be stored at 4°C immediately after filling. The sets of properly identified jars to be used are prepared prior to the sampling activity.



6. EMERGENCY PLAN

6.1 SPILL WITHIN THE LANDFARMING FACILITY.

A complete spill kit and tools will be located in place for fast response at any time. Any material used during a spill response will be replaced immediately. Whenever a spill occurs, the spill response will be initiated immediately when observed or noticed. The spills which are most likely to occur would result from equipment and vehicles working in the landfarm facility. The liquids to be encountered are fuel, gasoline, lubricating oil, hydraulic fluid, cooling liquids (ethylene glycol) and oily water resulting from a spill.

6.1.1 Fuel or gasoline:

The liquid portion will be absorbed with absorbent material and recovered to be burned on site in the used oils incinerator. The impacted soils area will be identified by survey points for future sampling purposes and treated in place.

6.1.2 Lubricating oil, hydraulic fluid:

The liquid portion will be absorbed with absorbent material and recovered to be burned on site in the used oils incinerator. The impacted soils will be excavated by hand and according to PHC concentrations, transported to the non-hazardous landfill or packaged for off-site disposal.

6.1.3 Ethylene glycol:

The liquid portion will be pumped into used ethylene glycol barrels for proper off-site disposal. The impacted soils will be hand excavated and packed in lined wooden sea-cans or lined super bags for off-site disposal.

6.1.4 Oily water resulting from a spill:

Oily water will be cleaned in place with absorbent material or collected and passed through the oil/water separator. The oil free water will be reused for moisture control in the landfarm facility.

6.2 MEMBRANE PUNCTURE / RUPTURE.

In the case of the geomembrane would be punctured during the placement of the contaminated soils or during the tilling operations, the soil would be removed from the damaged area. The geomembrane would be cleaned and repaired (patched) properly to prevent any leaks. The area will be identified by survey points and with yellow caution tape left on the repaired surface before placing the geotextile and new clean screened fine material back onto the membrane.

6.3 SOIL IN GREATER QUANTITY THAN EXPECTED

If PHC contaminated soil volumes, other than the ones already identified, have to be excavated and treated, the following options will be considered with respect to the priority indicated hereunder:

- If room is available in one of the two cells, the soil newly excavated will be placed over this area;
- If no room is available but a certain area present soils where the remediation have been completed, the clean soil will be removed from the facility and the free space will be used to place the newly excavated soils;

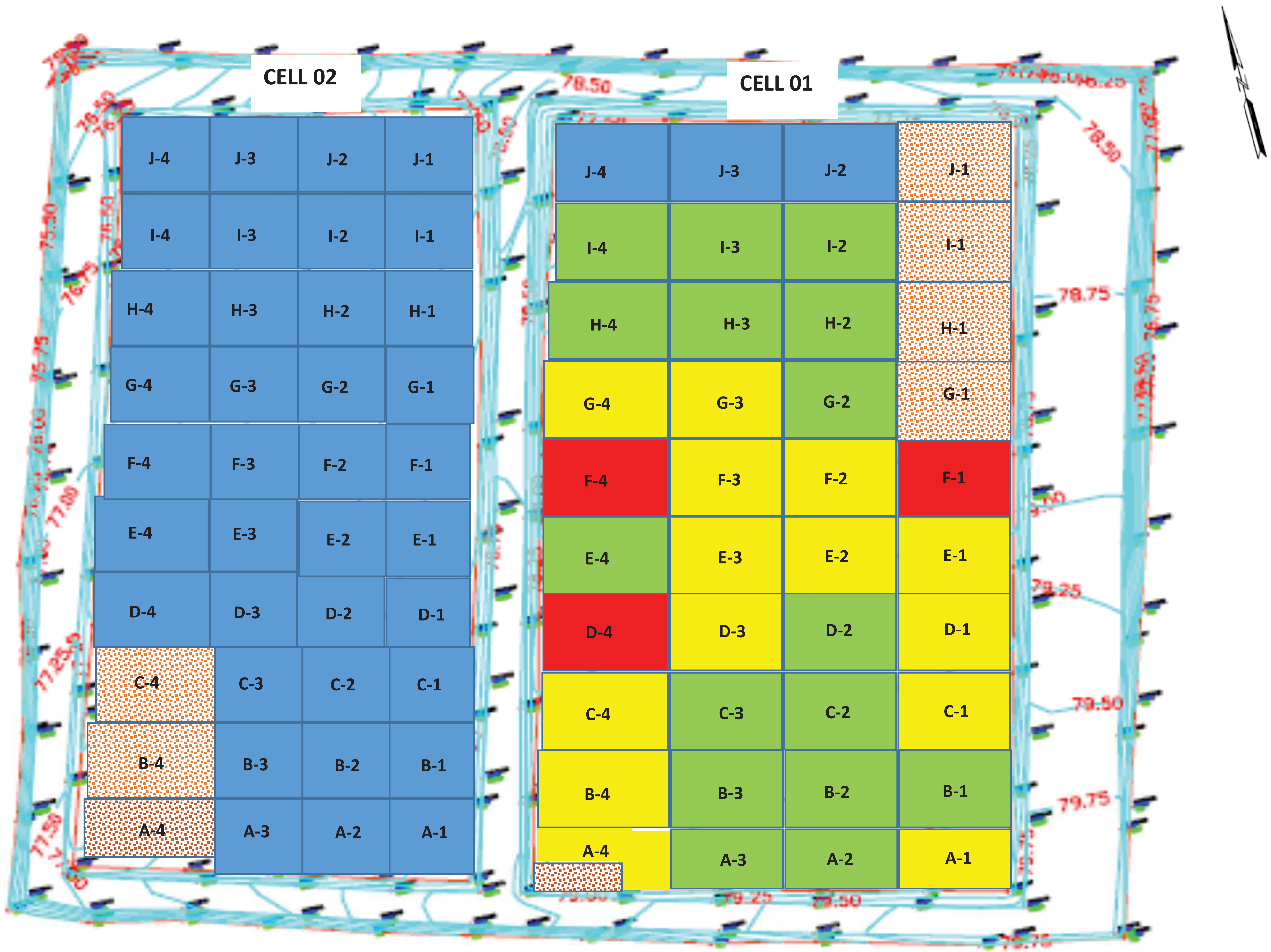
6.4 WATER ACCUMULATION WITHIN THE LANDFARMING FACILITY

During the course of the summer, water from precipitations may accumulate at the lower end of the landfarm facility. Any PHC accumulating on the water surface will be skimmed off and collected in an oil/water separator. The oil portion will be accumulated in barrels for testing and appropriate disposal. The interface portion will be kept in the oil/water separator for further separation and the water portion without free phase will be returned in the landfarm to be used to moisturize the soil being treated as needed. This process will be maintained during the entire landfarming period.

APPENDIX 1
FIGURE 2

CAM-E Soil Treatment Facilities

Figure 2: CAM-E Soil Treatment Facilities
Update: September 2017



- Rock stockpile
- No results
- F1+F2+F3 ≤ 2500 mg/Kg
- 2500 < F1+F2+F3 < 3000 mg/Kg
- F1+F2+F3 ≥ 3000 mg/Kg

Area (m2)		
	Total	Sampling
Cell 01	5814	145
Cell 02	4744	119

Analytical Results, PH F1+F2+F3				
	Cell 01		Cell 02	
Location	mg/kg	Date	mg/kg	Date
A-1	2968	Jul 31, 2017	--	--
A-2	1663	Jul 31, 2017	--	--
A-3	1446	Jul 31, 2017	--	--
A-4	2794	Jul 31, 2017	--	--
B-1	2984	Jul 31, 2017	--	--
B-2	2312	Jul 31, 2017	--	--
B-3	532	Jul 31, 2017	--	--
B-4	1727	Jul 31, 2017	--	--
C-1	2637	Jul 31, 2017	--	--
C-2	2407	Jul 31, 2017	--	--
C-3	1432	Jul 31, 2017	--	--
C-4	2705	Jul 31, 2017	--	--
D-1	3151	Jul 31, 2017	--	--
D-2	2685	Jul 31, 2017	--	--
D-3	2107	Jul 31, 2017	--	--
D-4	2946	Jul 31, 2017	--	--
E-1	2179	Jul 31, 2017	--	--
E-2	2632	Jul 31, 2017	--	--
E-3	2621	Jul 31, 2017	--	--
E-4	2530	Jul 31, 2017	--	--
F-1	3077	Jul 31, 2017	--	--
F-2	2758	Jul 31, 2017	--	--
F-3	2560	Jul 31, 2017	--	--
F-4	3257	Jul 31, 2017	--	--
G-1	2837	31-07-2017	--	--
G-2	2737	31-07-2017	--	--
G-3	2266	31-07-2017	--	--
G-4	2750	31-07-2017	--	--
H-1	1841	Aug 8, 2017	--	--
H-2	1670	Aug 8, 2017	--	--
H-3	1225	Aug 8, 2017	--	--
H-4	1112	Aug 8, 2017	--	--
I-1	2005	Aug 8, 2017	--	--
I-2	1927	Aug 8, 2017	--	--
I-3	1034	Aug 8, 2017	--	--
I-4	1396	Aug 8, 2017	--	--
J-1	--	--	--	--
J-2	--	--	--	--
J-3	--	--	--	--
J-4	--	--	--	--