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Canzinco
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Attn: Johan Skoglund, Group Manager Environment
e-mail Johan.skoglund@nyrstar.com

Dear Johan;

Re: Overview of the methodology/approach for developing Site Specific Soil Remediation Objectives (SSROs) for pre-determined project areas of the Nanisivik docksite.

1.0 OBJECTIVES

The objective of this letter is to describe the proposed approach for developing Site Specific Soil Remedial Objectives (SSROs) for soils with residual petroleum hydrocarbon contamination originating from the Nanisivik docksite tank farm. The information has been provided at the request of the Nunavut Water Board and AANDC as part of deliberations regarding the Canzinco *Application for Renewal and Amendment*.

2.0 BACKGROUND

Guidance on the development of a set of SSROs is being provided to Canzinco by Doug Bright, Ph.D., the author of this letter, and Gladys Stephenson, Ph.D.

Dr. Bright was the primary technical developer of the Canada Wide Standards for Petroleum Hydrocarbon (PHC CWS) for ecological receptors in 1998-99, and was later engaged by the Alberta government to participate in the Five Year Review of the PHC CWS. He was also engaged by Alberta Environment in 2008—2009 to develop Alberta Tier 2 approaches for derivation of SSROs for PHCs based on direct soil contact pathways (toxicity to soil invertebrates and plants).

Dr. Stephenson directed the development of the laboratory ecotoxicity data that underpins the PHC CWS generic soil values for direct exposure contact – soil invertebrates and plants, under contract with the Canadian Association of Petroleum Producers (CAPP) and the Petroleum Technology Alliance of Canada (PTAC). She and her colleagues at Stantec have more experience than any other group of researchers worldwide in the development of SSROs for petroleum hydrocarbon contaminated sites based on the application of standardized plant and soil laboratory toxicity test methods.

The basic intent of Canadian soil quality guidelines/standards is the same regardless of whether soil chemistry results for a site are compared with (Tier I) generic environmental quality guidelines or (Tier II & III) site specific environmental quality guidelines such as SSROs: i.e. **to provide assurance that the ecological function will be sustained within a given land use function** (CCME 2006[1]). The PHC CWS soil standards for protection of soil ecological functioning aim to prevent inhibition of plant community productivity and biodiversity as a result of a toxicological effect of petroleum hydrocarbon constituents.

The PHC CWS for Fractions F1 (nC6 to nC10), F2 (nC10-nC16), F3 (nC16-nC34) and F4 (effective boiling point range > nC34) were derived using laboratory ecotoxicity response data for growth and yield in plants (northern wheatgrass, alfalfa, and barley) and survival and reproduction in soil invertebrates (columbollan: *Onychiurus folsomi*; earthworm species: *Eisenia andraei, Lumbicus terrestris*). The toxicity tests were performed in two soil types: a field-collected Delacour orthic black chernozem, and an artificial soil comprised of 70% silica sand, 20% kaolinite clay and10% sphagnum peat, spiked with fractionated samples of a sweet crude oil (whole Federated Crude).

The thresholds of effects for each plant or invertebrate species theoretically will depend on the soil characteristics, specific characteristics of the petroleum hydrocarbon mixture in the soil, and interactions of the soil and PHC characteristics relevant to the degree of bioavailability within the rhizosphere. The ecotoxicity data that support the PHC CWS may not be a good reflection of plant community responses to CWS F2 range hydrocarbons in soils from the Nanisivik docksite, therefore, to the extent that –

- The composition of F2 hydrocarbons in Nanisivik dock site soils (primarily diesel) is different from the fractionated whole federated crude, with accompanying differences in the individual and cumulative toxicity of the various aliphatic and aromatic constituents;
- The soils at the Nanisivik docksite are sufficiently different from those used in the PHC CWS tests in terms of sediment texture, organic carbon content, water holding capacity, pH, or other properties to alter the dose-response relationships and/or bioavailability; and/or

[1] CCME (Canadian Council of Ministers of the Environment), 2006. A Protocol for the Derivation of Environmental and Human Health Soil Quality Guidelines.

- The plant and soil invertebrate species and communities that occur naturally at the Nanisivik dock site exhibit a different sensitivity to PHC soil contamination in comparison with those species used to develop the generic PHC CWS.

Approximately 17,000 m^3 of soils at the Nanisivik docksite were estimated to be contaminated by gasoline or diesel fuel in 2011. Of the four CWS fractions, only the concentrations of Fraction F2 are expected exceed their respective soil quality standards following excavation and on-site handling. Based on *ex situ* bioremediation efforts to the end of summer, 2014, the estimated range of PHC F2 hydrocarbon concentrations in the soil of interest is from less than detection (<10 mg/kg) to approximately 1,000 mg/kg. Samples were received by the lab Sept 3, 2014, and the most recent analytical results were not available at the time this memorandum was written. Approximately 6,500 m^3 of soils are being treated currently (by the end of 2014 field season).

The soils generally comprise coarse, sand and gravel glacial tills with little organic matter, excavated from subsurface areas within the active zone and into the upper permafrost zone. The area is also within an area of strong marine influence both based on past submersion by seawater prior to glacial rebound and routine contemporary exposures of the land mass to marine aerosols. The soils may also reflect naturally enhanced trace element concentrations (e.g. of lead, zinc and allied elements) as a result of local mineralization. Extensive mineralization of bedrock outcrops in the general vicinity of the site are evident as gossans: areas with extensive iron-oxide staining that represent intensely oxidized and weathered rock.

3.0 APPROACH FOR DEVELOPMENT OF A SSRO FOR NANISIVIK DOCKSITE SOILS

Direct use of the generic PHC CWS value for fraction F2 (direct soil contact, soil invertebrates and plants: 260 mg/kg for a commercial or industrial site) at the Nanisivik Docksite may not provide an accurate estimation of the soil concentration threshold above which plant ecological function may be impaired. Therefore, a set of SSROs is being developed. A three-pronged approach for developing SSROs has been implemented, as described below.

3.1 COMPARATIVE RESPONSE IN LABORATORY TESTS OF PLANTS AND SOIL INVERTEBRATES GROWN IN MINIMALLY CONTAMINATED SOILS AND THOSE WITH PHC F2 > 260 MG/KG

Bulk samples of four site soils from excavated areas in the vicinity of the former tank farm were collected and sent to the Guelph, ON, environmental toxicology laboratory operated by Stantec Consulting Ltd., under the guidance of Dr. Gladys Stephenson. The four samples included one reference control sample and three additional samples collected to span the range of residual CWS F2 concentrations >260 mg/kg F2 at the site as of July 2014. The concentrations of the field collected samples at the time of collection were estimated to be approximately 130 mg/kg, 440 mg/kg, 610 mg/kg, and 1060 mg/kg.

After consideration of the types of vegetation that occur at the Nanisivik docksite, a test battery of three plant species was selected from among the available standardized toxicity test species, per Environment Canada methods. Some of the plant species commonly observed at the dock site (A. Laudrum, pers. com.) include the following:

Arctic willow (*Salix arctica*)	Snow cinquefoil (*Potentilla nivea*)
Net-veined willow (*Salix reticulate*)	Mountain sorrel
Green alder (*Alnus crispa*)	Purple mountain saxifrage (*Saxifrage oppositifilic*)
Dwarf birch (*Betula glandulosa*)	Yellow oxytrope (*Oxytropis maydelliana*)
Arctic cottongrass (*Eriophorum scheuchzeri*)	Purple bladder campion (*Melandrium apetalum*)
Fragile Fern (*Crystopteris fragilis*)	Moss campion (*Silen acaulis)*
Lyme grass (*Elymus arenarius*)	Arctic poppy (*Papaver radicatum*)
Blue Grass (*Poa* sp.)	Capitate lousewort (*Pedicularius capitata*)
Arctic bladderpod (*Lesquerella arctica*)	Wolly lousewort (*Pedicularius lanata*)
Arctic dryad/ mountain avens (*Dryas integrifolia)*	Arctic lousewort (*Pedicularius arctica*)

Since culture and toxicity test methods have not been developed for these or other species, three plant species as follows were selected for laboratory toxicity testing:

- Northern wheatgrass (*Elymus lanceolatus*): species identified as part of the development of the PHC CWS as being most sensitive to F2 and F3 hydrocarbon contamination. Allied species to *E. arenarius* that grows on site.

- Alfalfa (*Medicago sativa*): surrogate for other arctic nitrogen-fixing species.

- Brue grama grass (*Bouteloua gracilis*): C4 perennial grass that occurs extensively in prairie ecosystems from northern Manitoba to New Mexico.

In addition, the collembolan *Folsomia candida* was selected for testing. While *F. candida* may not occur in arctic soils, preliminary data suggest that the sensitivity of this species to petroleum hydrocarbon contamination is similar to that of *F. nivalis*, which occurs extensively in Canadian arctic terrestrial ecosystems. Earthworm species were not included in the test battery, since earthworms such as *E. andraei* and *L. terrestris* are not native to Canada, and do not occur in arctic soils. Few native earthworm species exist in Canada, being generally present in small areas of the country that escaped glaciation in the last 20,000 years.

The number of test species and endpoints selected is only slightly less that was used to develop the original generic PHC CWS for protection of soil invertebrate and plants, and is considered to be adequate to develop a credible SSRO for PHC F2 contaminated site soils without undue uncertainty.

Plant species were grown in screened and bioremediated soils sourced from the site for a period of 21 to 28 days. The test units, run in triplicate for each bulk soil sample, were then disassembled at the measurements made of root length, shoot length, root wet mass and dry mass, and shoot wet mass and dry mass. *F. candida* tests were run for 28 days after which survival and number of progeny were assessed.

The initial data analysis approach will be to examine whether there is a statistically significant difference in the biological responses between the most contaminated soil samples and the <220 mg/kg F2 reference soil.

3.2 Use of Laboratory Ecotoxicity Test Results to Develop an SSRO Based CCME (2006) Soil Quality Guideline Derivation protocols

If no adverse response in plant growth or collembolan survival or reproduction is observed in the test units with the highest soil F2 concentrations, then it will be concluded that the risks to plant community productivity at the site are adequately low. Conversely, if a significant response is observed in the higher concentration test soils, the data will be used to fit a concentration-response relationship for each species and measurement endpoint (as was completed for the development of the PHC CWS) and if possible an EC_{25} effects concentration will be estimated. The EC_{25} endpoints for the four species and various endpoints will then be used to develop a species sensitivity distribution (SSD) and in turn a 50^{th} percentile SSD estimate as the SSRO (industrial land use) for the Nanisivik dock site soils. The derivation procedures used to calculate the PHC CWS soil standards (soil invertebrates and Plants) as updated in 2008 wil be used to calculate the Nanisivik docksite SSROs.

3.3 Native Plant Responses in Field Soil Plots at the Nanisivik Dock Site – Transplant Trials

In parallel with the laboratory toxicity tests discussed above, field plots were established at the dock Site in July of 2014. The plots (VPL, VPM, VPH – low, medium, high concentration soils within the available range of on-site concentrations) were constructed using biopile soils (CWS F2 = 440 mg/kg or 660 mk/kg on average) or a local uncontaminated reference soil, established in triplicate. Each plot was planted with clones of arctic willow *(Salix* sp.: n = 2), arctic cotton *(Eriophorum scheuchzeri*: n = 2), another sedge (n = 3) and arctic fireweed (*Chamerion latifolium (*n = 2).

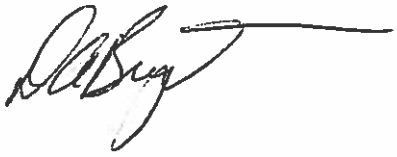
Toward the middle of the active growing season in 2015, the root and shoot length and biomass for all transplanted and volunteer plants will be measured in the plots, and samples of soil collected for the analysis of hydrocarbon concentrations. These data are intended to reflect the most realistic estimate of

PHC F2 toxicity thresholds to local plant species and communities, and permit an updated evaluation of ecological risks to arctic plants from residual PHC concentrations in soils.

4.0 CLOSURE

I trust that this report is satisfactory to your requirements. Please feel free to contact the undersigned regarding any questions or further information that you may require.

Report prepared by:
Hemmera



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