03/04/2006

Five-year review of the Canada-Wide Standards for Petroleum Hydrocarbons (PHC CWS):

Ecological, Direct Soil Contact Guidance

Report to the Canadian Council of Ministers of Environment (CCME) Soil Quality Guidelines Task Group (SQGTG)

By the Ecological Criteria Advisory Sub Group

March, 2006

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1. Introduction

Canada has been among the first of jurisdictions to develop a set of consistent, generically applicable, environmental (ecological and human health) risk-based assessment and remediation guidelines for refined and unrefined petroleum hydrocarbon releases to soil ecosystems. Canada-Wide Standards for Petroleum Hydrocarbons (**PHC CWS**) were developed in 1998-99, based on significant new approaches and new scientific studies on both human health effects and effects on soil productivity and ecological functioning. The PHC CWS are intended to address risks from: hydrocarbon releases to human health; to aquatic life based on groundwater-mediated transport of hydrocarbons; to livestock in agricultural systems; and, in particular, to agronomic plant productivity or plant community 'health' in non-agronomic settings. The PHC CWS were also intended to address risks to soil microarthropods and various other soil fauna that are considered to be important in maintaining a minimum level of soil ecological functioning.

During the initial development of the PHC CWS, the PHC CWS Development Committee was lead by Alberta as the Champion for this Canada-Wide Standard[1]. The Canada-Wide Standards development and implementation was facilitated, in part, through the Canadian Council of Ministers of the Environment (**CCME**) framework. The PHC CWS Development Committee was assisted in the initial development of the PHC CWS by input from three multi-stakeholder technical expert groups, each with representation from academia, the oil and gas sector, environmental consulting sector, and environmental regulators. The groups included the following:

- Human Health, Fate and Transport Technical Advisory Group (**HHFTTAG**);
- Ecological Technical Advisory Group (**EcoTAG**);
- Analytical Methods Technical Advisory Group (**AmTAG**).

The reader is referred to CCME (2000, 2001 a,b) for an account of the scope of discussions, group representation, issues discussed, critical decision points, and outcomes of deliberations.

Several aspects of the PHC CWS made it ground-breaking in nature, but at the same time stimulated a desire to assess the extent to which they accomplished their intended objectives within the initial years; i.e., protection of human health and the environment, for cases where petroleum hydrocarbons had been released to the environment. Ideally, such protection should be enacted in a manner that strikes a balance between the degree of uncertainty about concentration-effect relationships and the desire to avoid a financial burden beyond what may be required to resolve the actual environmental risks.

A major aspect of the PHC CWS was the establishment of an operational definition of petroleum hydrocarbons that was intended to accommodate known differences in the types of petroleum products potentially released to the environment, as well as significant differences in their expected volatility, aqueous solubility, persistence in soil systems, and partitioning into organic-carbon and lipid-rich matrices (including living organisms). Four PHC CWS fractions were established, as follows:

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[1] During the same period, Canada-Wide Standards were also developed for dioxins/furans, benzene, ground level ozone, particulate matter, and mercury. These five CWS are based largely on source inventories and source control measures, whereas the PHC CWS is unique in being a set of soil quality standards to provide the mechanism for standardized approaches across Canadian jurisdictions to hydrocarbon releases.

- **CWS Fraction 1 (F1):** all aliphatic, aromatic, and assorted petroleum-based hydrocarbons with an effective boiling point range that results in elution on a GC column based on boiling point separation between the peak of *n*-hexane (*n*C6) and *n*-decane (nC_{10}). Exceptions to this are the compounds benzene, toluene, ethylbenzene, and xylenes (BTEX compounds), which are separately managed using CCME soil quality guidelines and/or provincial soil standards or guidelines.

- **CWS Fraction 2 (F2):** all petroleum-based hydrocarbons as above with an effective boiling point range between *n*-decane (nC_{10}) and nC_{16}, excluding naphthalene.

- **CWS Fraction 3 (F3):** all petroleum-based hydrocarbons as above with an effective boiling point range bounded by the elution peak of nC_{16} and nC_{34}.

- **CWS Fraction 4 (F4):** all petroleum-based hydrocarbons as above with an effective boiling point range greater than nC_{34}.

Fresh motor gas (mogas) 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.

The four PHC CWS fractions were derived based in large part, on extensive prior scientific review and analysis of petroleum product composition, hydrocarbon fate, and human toxicity thresholds, originally undertaken in the United States by the Total Petroleum Hydrocarbon Criterion Working Group (**TPHCWG**). The four PHC CWS fractions are a “roll-up” of the 17 TPHCWG sub-fractions.

Because the PHC CWS four fractions comprised a new operational definition to both science and the environmental regulation of petroleum hydrocarbons, the scientific literature provided very few toxicity data that were useful for establishing soil guidelines that would be effective for soil invertebrate and plant protection based on direct contact. The PHC soil quality guidelines developed, therefore, were based almost entirely on a set of new laboratory-based, soil ecotoxicity studies conducted by ESG (now Stantec), with support from the Petroleum Technology Alliance of Canada, through its funding partners, including the Canadian Association of Petroleum Producers (CAPP), Canadian Petroleum Products Institute (CPPI), Alberta Environment (AENV) and others. Some data were available through studies supported by the Quebec Ministry of Environment and Environment Canada. In addition, syntheses of the new ecotoxicity data were critically evaluated in light of existing studies on the effects on individual (surrogate) compounds or whole product releases (crude, diesel, naphtha, etc.) on soil flora and fauna.

The new ecotoxicity data were developed using a laboratory fractionated, fresh, relatively sweet crude oil (Whole Federated Crude) from an Alberta source, as well as two soil types – an artificial (OECD) soil, and a field-collected, relatively fine-textured Chernozem loam. Virtually all ecotoxicity data for CWS fractions generated since 1999 is based on this particular petroleum source. Some additional data exist, using the same test species and similar test methods, for motor gasoline (mogas). There remains concern that the fresh crude represents a narrow range of composition relative to the expected types of petroleum hydrocarbon releases that must be effectively managed in Canada. The combination of the limited number of species used to develop the toxicity data (all best suited to agronomic settings), limited range of product types examined toxicologically, and limited types of soils used in laboratory toxicity tests have been criticized as a large source of uncertainty for management of the risks associated with soil contamination.

When the PHC CWS was endorsed by the Federal, Provincial and Territorial Ministers of the Environment, in 1999, it was considered prudent to formally include a five-year review, which would take advantage of new scientific/technical information that was expected to come to the fore in light of the new management regime, as well as effort given during the development process to identifying scientific data gaps. In preparation for this five year review, the CCME Soil Quality Guidelines Task Group (**SQGTG**) in 2004, sponsored the review of new relevant scientific research and development work completed since 1999 (Tindal and Bright, Mar. 2004).

Further to the analysis in the Tindal and Bright (2004) report, the SQGTG began in earnest an extensive review of the PHC CWS in early 2005. To assist them with their review, the SQGTG convened a technical working group, the "**Ecological Criteria Advisory Sub Group**" (**EcoSG**) to assist with critical evaluation of the scientific basis, validity, and accuracy of PHC soil guidelines developed in consideration of effects on plants and soil fauna based on direct contact exposures in surface soil systems[2]. **This report provides a summary of the deliberations and recommendations of the EcoSG[3].**

Individuals who contributed to the review and revision of the Petroleum Hydrocarbon Canada-Wide Standards through their participation in the EcoSG are listed in Appendix A.

1.1 Objectives

The deliberations of the EcoSG were guided initially by a Terms of Reference (**ToR**: Appendix B). The scope of discussions and analysis was initially narrowed by the SQGTG in reflection of the previous review (Tindal and Bright, 2004), as well as extensive informal consultations with various stakeholders regarding priority issues, and the major drivers for site assessment and remediation based on the previous, approximate five years of experience.

For example, managing risks of F1 hydrocarbons in subsurface soils below impervious surfaces remains a significant issue in urbanized environments at gas stations and other locations where leaking underground storage tanks have been identified. Soil standards for CWS Fraction F3 from crude oil releases are of particular interest for environmental practitioners and stakeholders in rural or undeveloped areas, in light of the extensive observations that (i) F3 potentially encompasses a wide range of different compounds; (ii) the higher molecular weight compounds in this fraction are more recalcitrant to microbial biodegradation in soils or volatilization; and (iii)

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[2] The potential for risks to soil-dwelling organisms from petroleum hydrocarbon contaminated soils is predicated on a viable exposure pathway; i.e., presence of contaminants within the potential rooting or burrowing zone. In the 1999 PHC CWS (CCME, 2000), management/remediation objectives were established for sub-surface soils that were based in part on protection against risks to soil invertebrates and plants. This is discussed farther on in the report.

[3] In addition to the EcoSG, several other technical working groups were tasked by the SQGTG to work concurrently on other aspects of the PHC CWS such as indoor intrusion of contaminated soil vapours, predicting groundwater mediated exposures, and human toxicity reference values. Interested readers are referred to reports by the other technical sub-groups.

there may be significant potential for a lower realized toxicity for weathered, aged releases, owing to limited bioavailability.

On the basis of the above referenced review scope considerations, the objectives of the EcoSG were the following:

- Briefly review the Terms of Reference and propose changes with an accompanying rationale;
- Undertake scientific reviews of critical issues of relevance to understanding and managing risks to soil invertebrates and plants exposed to petroleum hydrocarbon mixtures in soil;
- In light of the best available scientific information, review the existing PHC CWS in terms of their derivation particulars as well as the realized level of biological effects, especially in field studies, relative to narrative protection goals;
- Propose changes to the existing generic soil quality guidelines, as appropriate, and provide a clear and unequivocal scientific rationale;
- Identify those critical components of the soil quality guideline development that may require policy decisions from the SQGTG; and,
- Assist with development of further site-specific approaches to addressing petroleum hydrocarbon risks to soil systems.

Environmental management approaches invariably require simplification of what is typically complex underlying scientific information, including large areas of uncertainty and unknowns, detailed deliberations around mitigating factors or confounding influences of cause-effect relationships, and a rapid state of flux in the knowledge base. The requisite guidance is strengthened to the extent that there is greater scientific consensus around and issue, and resultant reduction in the uncertainty about the outcome of a proposed approach or use of a particular tool.

As such, the EcoSG strove to provide the SQGTG with clear guidance by advancing those pertinent issues and the suggestions for guideline revisions that were based on consensus. Several innovative and at times speculative approaches came to light in the discussions that – while fertile ground for scientific research – were deemed to be too immature to assist with pragmatic management approaches. In a few specific cases, the EcoSG has recommended adoption of an approach for the specific purpose that we felt it would serve as a strong catalyst for studies that may have concrete management utility within the next 5-10 years.

The EcoSG deliberations and recommendations fell into two broad areas:

- A major priority was the critical evaluation of the existing generic numerical soil quality standards in light of discussions since 1999, on soil quality guideline derivation protocols in Canada, results from field studies of experimentally oiled soil plots, concerns raised in recent years regarding particulars of the original derivation, and new ecotoxicity data produced since 1999. The major sub-text to these deliberations was based on the questions: "Did we get it right? Is there evidence that the existing generic soil standards are inadequately protective in some circumstances? Conversely, are the existing guidelines overly protective (unnecessarily conservative) in some circumstances? Has our knowledge changed sufficiently since 1999-2000 to justify a change to the generic PHC soil quality standards?

- The second major area of focus was the possible development of approaches that might be used in Canadian jurisdictions for developing more site-specific site assessment and remediation objectives in consideration of ecological direct soil contact exposures in cases where use of generic soil standards might be inappropriate. The terminology that has been utilized by the CCME to describe a structured access to different levels of investigative effort at a site en route to implementing risk management solutions is as follows: Tier 1 - development and use of generic numerical environmental quality guidelines (including the PHC CWS); Tier 2 – incorporation of more site-specific information toward a re-calculation of numerical environmental quality guidelines (typically in the past by replacing assumed site characteristics with measured site characteristics, in cases where contaminant concentrations at the point of exposure were estimated with a predictive model); and Tier 3 – detailed quantitative human health and ecological risk assessment, the methodology for which is highly tailored to site conditions.

  The EcoSG was specifically tasked with evaluating options for and the issues associated with possible Tier 2 approaches for the ecological direct contact pathway. As discussed in subsequent chapters, the focus of Tier 2 deliberations was on the use of ecotoxicity tests to develop site-specific remediation objectives, and methods that might estimate degree of bioavailability from soil.

1.2 Report Structure

The remaining sections of this report are structured as follows:

Section 2: Summary of Major Outstanding Scientific/Technical Issues for the PHC CWS Ecological Direct Contact Standards, and Scope of the EcoSG Deliberations

Section 3: Background Information – Relevant CCME/CWS Environmental Protection Goals

Section 4: Review of the Generic Numerical (Tier I) Soil Standards for Protection of Soil Invertebrates and Plants

Section 5: Development of Tier 2/3 Approaches for PHC Contaminated Sites.

Section 6: Continuing Knowledge Gaps

Section 7: SQGTG Policy Decision Requirements

Section 8: Summary Recommendations of the EcoSG

Section 9: References Cited

2. Summary of Priority Technical/Scientific Issues for the PHC CWS

A concise summary of the major issues that have been identified during (1998-99) and subsequent to (2000-05) the development of the PHC CWS is provided in Table 2.1. Note that the numbering of issues is consistent with an initial list established by the SQGTG, from which only a subset of issues was forwarded to the EcoSG.

Several additional issues were identified by EcoSG. For example, discussion took place on CWS Fractions 1, 2, and 4, in addition to those listed below for Fraction 3. Many of the identified issues were often linked in terms of discussion and associated review. As such, the reader is encouraged to review the following report Sections 4 to 8, inclusive, for issues outcomes, including our assessment and recommendations.

Table 2.1: Summary of Priority Issues Addressed by the Ecological Criteria Advisory Sub Group

Issues Pertaining to Existing Tier 1 Soil Standards	
Issue 7.	• **Toxicity of weathered hydrocarbons relative to Tier 1,** • **Appropriateness of F3 ecological soil guidelines, based especially on potential effects of weathering on toxicity.**
	Issue Summary: Weathered and aged PHCs may be less bioavailable/toxic than the fresh product (fractioned fresh whole federated crude) used for the CWS bioassay tests. If so, current guideline value may be overly conservative for weathered and aged PHCs. • "Industry believes that soils that still contain weathered/aged fraction F3 concentrations above current guidelines following extensive bioremediation or natural attenuation, probably do not display significant toxicity to plants and terrestrial invertebrates." - CAPP submission CCME (2005) protocols recommend that toxicity data used to derive generic soil guidelines be carefully assessed for experimental conditions where less than 100% bioavailability may have occurred. The two test soils contain higher organic C than some site soils (e.g. sandy soils) and an assumption of high bioavailability in the original tests might not be warranted.
Issue 9:	**Review of the use of EC50 in establishing the soil eco-toxicity criteria**
	Issue Summary: • "Revisions to the CCME protocols in 2003, currently in draft, proposed that a weight-of-evidence approach for deriving soil quality guidelines based on direct soil contact utilize a standardized effects level of EC_{25} as opposed to EC_{50}. The underlying rationale is that 50% reduction in growth, yield, reproduction, or some other ecologically relevant response factor may be too high relative to policy-based environmental protection goals." –UMA/Axiom • The revised "Protocol for the Derivation of Environmental and Human Health Soil Quality Guidelines" notes use of the EC_{25} rather than EC_{50} • The use of the EC_{50} value, as in the current PHC guidelines, presented some concerns with respect to lethal response in invertebrates at the established guideline value. • There has been considerable concern raised with respect to use of the 25th

	percentile of the EC_{50} and other jurisdictions (e.g. BC science advisory board) have suggested use of a more stringent standard. • There were socio-economic reasons cited for the original decision to use EC_{50} criteria. • Use of the EC_{50} was originally supported due to factors that suggested lab and field response would not be the same. Additional data is now available for this, although it is uncertain that this data can be applied in a quantitative sense.
Issue 11:	**Correction for F3 analytical recovery**
	Issue Summary: PHC analysis during the original toxicity testing did not use the method finally adopted for the CWS. It has been suggested by some submissions that the difference in nominal versus initial values could be assigned to analytical recovery of the method used. Since the final guideline values were adjusted for the low recovery, if recoveries were significantly improved by the CWS method, this may lead to higher guideline values. In the review by the working group, it was noted that there are discrepancies between the appendix by CAPP and the data in the original ESG reports that make direct comparison problematic and assignment to analytical recovery shortcomings difficult. In particular, time dependant experimental losses do not mirror each other in the two studies except for very high concentrations in the original ESG report where higher analytical recoveries were reported. Concerns were raised that appropriate review of this information may require complete repetition of the original data set, which would be costly and time consuming. It was also noted that information submitted was not complete and the complete information package may be able to shed some light on these concerns.
Issue 15:	**Stringency of the F3 standards**
	Issue Summary: Several groups claim that the current F3 standards are too stringent and should be reviewed because the F3 fraction is the main driver for site remediation and it is difficult to biodegrade; thus the standards are not easily met. It has been argued, however, that the technology does exist some firms are successful at removing F3 fraction using engineered and efficient biological treatment processes, and they have found that in most cases F3 can be remediated to the present standards.
Issues Pertaining to a Possible Tier 2 Approach (Development of Site-Specific Remediation Objectives)	
Issue 8:	**Development of bioavailability index in place of total extractable hydrocarbons**
	Issue Summary: • It was suggested that it may be possible to refine the practical implementation of the ecological soil contact guidelines in the field, especially through development of Tier 2 guidelines for this exposure pathway. A technique that could prove useful for site-specific approaches is using analytical methods of estimating the bioavailable portion hydrocarbons together with limited toxicological testing to confirm whether a bio-remediated soil has reached a non-toxic endpoint. • CAPP suggests that "the lack of predictive models relating soil properties to PHC bioavailability or toxicity is the main reason for advocating the actual measurement of biological response potential at any given site, as opposed to reliance on chemical analysis of soil concentrations." They go on to express that there is a promising experimental approach for estimating bioavailability included in

	cyclodextrin-based extraction. Information on the cyclodextrin-based extraction was limited and it is unclear whether this is sufficiently robust to be used in a quantitative sense.
Issue 14:	**Development of Tier 2 guidance for eco contact**
	Issue Summary: No mechanism is currently available to perform Tier 2 adjustments to eco-contact guidelines. CAPP and CPPI have requested that a method be developed that would allow for adjustments of the eco-contact pathway at the tier 2 level. This issue was largely developed to address the issue around toxicity of weathered hydrocarbon and potential for development of a bioavailibility index (issues 7 and 8).

2.1 Scope of Deliberations

The detailed scope of deliberations of the Ecological Criteria Sub Group was as follows:

1) **Review all relevant information submitted to CCME with respect to ecotoxicity of petroleum hydrocarbons in soil**. This includes information on appropriate effects concentration to apply in the Canada-Wide Standard, and information supporting revisions based on toxicity and bioavailability of weathered hydrocarbons and potential for use of these factors under a Tier 2 protocol.

2) **Obtain and review any information that may be directly relevant to submissions that were made to CCME.**

3) **Develop terms of reference for, and direct any research/review activities that may be undertaken to complete the task.**

4) **Examine relevant policy and protocol decisions that have been developed since the original CCME PHC CWS**.

5) **Determine if there are relevant and significant technical or policy changes since the development of the CCME PHC CWS** that might result in substantial changes to the current toxicity guidelines.

6) **In keeping with the appropriate CCME protocol framework, develop updated recommendations and rationale for ecological toxicity reference values and guidance documents**.

7) **Prepare a final report including the recommendations and rationale for any necessary updates to the CCME PHC CWS standard for the SQGTG.**

3. Overview of the Intent of Canadian Soil Quality Guidelines for Protection of Soil Ecological Functioning (soil invertebrates and plants)[4]

The PHC CWS is a specialized case of Canadian (CCME) Soil Quality Guidelines. Canadian Soil Quality Guidelines (CSQG) consider both human health and ecological receptors, and are intended as general guidance for the protection, maintenance, and improvement of specific uses of land and water. Recommended CCME Soil Quality Guidelines have been developed for four different land-uses with defined exposure scenarios:

- Agricultural;
- Residential/Parkland;
- Commercial; and,
- Industrial.

Soil Quality Guidelines can be used as benchmarks to evaluate the need for further investigation or remediation with respect to a specified land use. Guidelines are applied to identify and classify sites, to assess the general degree of contamination at a site and to determine the need for further action, and as a basis for remediation objectives.

Development of Canadian Soil Quality Guidelines began in 1990. The use of formalized risk-based approaches for deriving CSQG was first codified in the 1996 Protocol for the Derivation of Environmental and Human Health Soil Quality Guidelines. For each guideline, a comprehensive review of the literature is conducted and a detailed assessment of the substance is prepared. The assessment, which may be a useful decision support tool for the site manager, includes:

- Production and uses in Canada;
- Existing criteria and guidelines;
- Levels in the Canadian environment;
- Environmental fate and behaviour; and,
- Human, terrestrial plant and animal toxicology.

Each technical supporting document includes details used to derive the recommended CCME Soil Quality Guidelines for human health and/or for ecological receptors for each of the four land uses (i.e., agricultural, residential/parkland, commercial, and industrial).

Derivation of the PHC CWS in 1998-99 was a major impetus for a re-evaluation of the 1996 CCME derivation protocols, since methods used to derive soil standards for both ecological and human health protection involved a much higher level of effort and discussion than was previously afforded CSQG derivation exercises. One aspect of the change with respect to soil invertebrate and plant protection, was the movement away from use of ranked “effects – no effects” data distributions, which comprise combinations of many types of toxicological endpoints, to a Weight of Evidence approach intended more accurately predict the “Species Sensitivity Distribution” (**SSD**).

[4] (adapted in part from http://www.ec.gc.ca/CEQG-RCQE/English/Ceqg/Soil/default.cfm)

Subsequent deliberations have resulted in development of updated CCME protocols for the derivation of generic numerical soil quality guidelines (CCME, 2005 – still in draft). Departures from the approach used to develop the PHC CWS (CCME, 2000) and recommended in CCME (2005-draft) are discussed in detail in Section 4. Key areas of potential discrepancy include: (i) use of EC25 (or IC25) instead EC/IC50 data to construct species sensitivity distributions when applying a Weight-of-Evidence derivation approach; (ii) addition of prescribed checks and balances to identify potentially redundant data points prior to developing an apparent SSD; (iii) potential use of uncertainty factors for the Weight-of-Evidence approach; and (iv) use of both the plant and soil invertebrate data for developing soil quality guidelines for commercial and industrial type sites.

According to CCME[4], soil quality guidelines should not be regarded as blanket values for national soil quality. Variations in environmental conditions across Canada will affect soil quality in different ways and many of the guidelines may need to be modified according to local conditions, such as at sites where there are high natural background levels of a contaminant, where atypical levels of organic carbon content could affect the mobility and/or bioavailability of the contaminant, or where the data for a species are irrelevant to the site under investigation.

Site-specific soil quality objectives are established to reflect the local environment and may be adopted by a jurisdiction into legislation to ultimately become standards. Where soils are of exceptional quality, or where they support valuable biological resources (e.g., endangered species), it is the policy of the CCME that degradation of the existing soil quality to the guideline value should always be avoided. Similarly, modifications of guidelines to site-specific objectives should not be made on the basis of soil characteristics that have arisen as a direct result of previous human activities.

The use of CSQGs for site-specific soil quality objectives requires an understanding of the chemical, physical, and biological characteristics of the soil and an understanding of the behaviour of a substance once it is introduced into the environment. Factors affecting the application of the guidelines may include the following:

- the general characteristics of soils and groundwater;
- the effect of local environmental conditions on soil quality;
- processes influencing the concentration of parameters in soil; and,
- factors that modify toxicity to terrestrial organisms.

With specific regard to soil functioning and soil invertebrate/plant protection, according to CCME (2005 – draft) (Section 2.1):

> "The level of protection provided by the guidelines depends on the protection goals sought for individual land use categories. Therefore, for agricultural and residential/parkland land use, it is necessary to achieve a level of ecological functioning that sustains the primary activities associated with these land uses. To make this possible, soil quality guidelines for these land uses are derived using laboratory and field toxicological data that make predictions on the adverse effects (effects that undermine a species' ability to survive and reproduce under normal living conditions) of chemicals on key ecological receptors. The protection goals and endpoints for agricultural and residential/parkland land use are described in Sections 5.1 and 5.2.

On commercial and industrial lands, the primary land use activities are not directly dependent on the need to sustain a high level of ecological processes. The same key ecological receptors and endpoints examined for agricultural and residential/parkland land uses are also examined for commercial and industrial land use. However, SQGTG has decided that the level of protection for commercial and industrial land use does not need to be as stringent as for agricultural or residential/parkland land uses. Accordingly, the degree to which commercial and industrial receptors may experience adverse effects is increased to correspond with the lower protection levels required for the land use category. For more information on the key receptors and level of protection sought for commercial and industrial land use see Section 5.3 and 5.4.

Despite the different levels of protection sought for individual land uses, an important common principle exists for all land use categories. For each land use, the level of ecological protection provided by the soil quality guidelines ensures that the remediated land has the potential to support most activities likely to be associated with that land use"

Section 5.1 of CCME (2005 – draft) states the following:

"5.1 Agricultural Land Use

In general, the primary activities associated with agricultural land use include the ability to grow crops and raise livestock. Although agricultural land use varies, the development of soil quality guidelines must protect key receptors that permit or maintain crop growth and livestock production against adverse effects. (Note: guidelines selection may include organisms that are subject to pesticide control.) Protection must also be offered to resident and transitory wildlife and native flora because, in some areas (e.g., agroecosystems), this may be the only viable habitat for these organisms."

"5.1.1 Growth of Crops and Plants

To ensure crop production at agricultural sites, it is essential to maintain soil-dependent biota whose ecological function sustains crop and plant growth. Contact of crops and native plants directly with contaminated soil must also be considered in guidelines development ."

"5.2 Residential/Parkland Land Use

The combination of different activities under one land use category can complicate the decision of which key receptors should be evaluated in an exposure scenario for residential/parkland land use. However, a common requirement among these land uses is to provide landscape and ecological settings that support the main land use activities (e.g., residential and parkland landscaping). Similar to agricultural land use, the development of soil quality guidelines for residential/parkland land use must ensure that the soil is capable of sustaining soil-dependent species and does not adversely affect wildlife from dermal contact and ingestion of contaminated soil or food."

"5.2.1 Growth of Ornamental and Native Flora

To ensure that residential/parkland land use can support both ornamental and native flora, soil-dependent biota (whose ecological function helps sustain plant growth) must be protected from adverse effects as a result of dermal contact with contaminated soil (see Figure 6). Dermal contact by plant roots and seeds must also be examined. Root uptake and accumulation of contaminants will be examined as it relates to the ingestion of plant matter by wildlife.

Sufficient toxicological information exists to consider dermal soil contact by microbes (and their effect on nutrient cycling), soil invertebrates (e.g., decomposers), and crops and plants (e.g., seeds and roots) for guidelines derivation for the protection of ornamental and native plant growth. Currently, there is insufficient information to incorporate dermal absorption and translocation of contaminants by crops and plants via aerial deposition into generic guidelines derivation, but these exposure pathways should be examined when information becomes available."

"5.3 Commercial Land Use

The nature of commercial land use is variable and can range from lands that approximate residential conditions (e.g., local gas stations) to lands that border on industrial activities (e.g., warehouses). This makes it difficult to describe key ecological receptors and exposure pathways for commercial land use. However, using the description of commercial land use in Section 2.3 of Part A, the degree to which maintenance of ecological functions is required will depend on the degree to which the site has been developed. From an ecological standpoint, SQGTG envisions generic commercial land to include managed (e.g., cultivated lawns, flowerbeds) as opposed to natural ecological areas (e.g., forests). The ecological receptors predicted to be present on commercial lands are similar to those identified for residential/parkland lands (i.e., soil dependent biota, wildlife) since these receptors sustain the managed ecological areas of commercial lands. However, on commercial lands, it is assumed that the normal land use activities do not depend on the maintenance of ecological functioning to the same degree as on agricultural or residential/parkland lands."

"5.4 Industrial Land Use

It is assumed that on industrial lands, activities may not rely on protecting key ecological receptors to the same degree as agricultural and residential/parkland land use. However, it is not the recommendation of SQGTG that areas of industrial lands not be able to support any ecological activity, and consequently be viewed as a portion of the landscape in which high levels of contamination are permitted. Therefore, soil quality guidelines will be developed for industrial land use, but will not offer the same level of protection from adverse effects as guidelines for agricultural and residential/parkland land use. Industrial land use guidelines will be derived for direct soil contact by soil-dependent biota and wildlife and will offer the same level of protection as commercial land use guidelines."

The policy decisions that emerge from this guidance assisted the EcoSG during their deliberations.

4. Re-evaluation of the Existing Generic (Tier 1) Numerical Soil Quality Standards for PHCs

Major issues in this thematic area addressed by the EcoSG included:

- Implications of differences in the derivation methodology between CCME (2000) and the most recent revisions to the derivation protocols (CCME, 2005- draft): *Section 4.1*;
- Re-evaluation of CWS F1 and F2 soil standards;
- Re-evaluation of CWS F3 and F4 soil standards; and,
- Guidance for deeper versus more shallow soils

4.1 Summary Comparison of Different Derivation Protocols

The EcoSG was tasked with examining differences in prescribed derivation methods as documented in CCME (1995), CCME (2000), and CCME (2005 – draft). The first and third of these are the initial CCME risk-based derivation protocols and latest update, respectively. CCME (2000) specifically discusses the derivation of the PHC CWS. In all cases, our interest was in procedures of direct relevance for calculation soil quality guidelines for the protection of soil invertebrates and plants. Table 4.1 provides a side-by-side comparison of the three approaches.

Glossary:

ECL:	Effects Concentration – Low
ESSD25:	25th %ile of the rank distribution, identified as the "estimated species sensitivity distribution – 25th percentile", used as the basis for soil contact guidelines for the agricultural and residential/parkland land uses (CCME, 2005).
ESSD50	50^{th} %tile of the rank distribution, identified as the "estimated species sensitivity distribution– 50th percentile", used as the basis for soil contact guidelines for the commercial and industrial land uses (CCME, 2005).
LOEC:	Lowest Observed Effects Concentration
NOEC:	No Observed Effects Concentration
NPER:	No Potential Effects Range
SQG:	Soil Quality Guideline
SQG_E:	Soil Quality Guideline for Ecological Protection
SSD:	Species Sensitivity Distribution
TEC:	Threshold Effects Concentration
WoE:	Weight of Evidence
$LC_x/EC_x/IC_x$:	x% Lethal/Effect/Inhibition Concentration

Table 4-1: Summary of Different Derivation Protocols

	CCME (1996)	PHC CWS	CCME (2005)
Objective			
	"Ensure that soil is capable of sustaining soil dependent organisms (agricultural and residential/parkland land uses)"	"preserve the principal ecological functions performed by the soil resource".	"developed to maintain important ecological functions that support activities associated with the identified land uses." **Agricultural:** soil quality guidelines must protect key receptors that permit or maintain crop growth and livestock production against adverse effects." **R/P:** "must ensure that the soil is capable of sustaining soil-dependent species" **Commercial:** "The ecological receptors predicted to be present on commercial lands are similar to those identified for residential/parkland lands (i.e., soil dependent biota, wildlife) since these receptors sustain the managed ecological areas of commercial lands. However, on commercial lands, it is assumed that the normal land use activities do not depend on the maintenance of ecological functioning to the same degree as on agricultural or residential/parkland lands."

	CCME (1996)	PHC CWS	CCME (2005)
			Industrial: "will offer the same level of protection as commercial land use guidelines."
1) Available Methods			
	1) Weight of Evidence (WoE) method 2) LOEC method 3) Median effects method	Weight of Evidence; however, based on reconstruction of Species Sensitivity Distributions (SSDs)	**Available Methods** 1) Weight of Evidence (WoE) method, based on adaptation of CWS SSD method 2) LOEC method 3) Median effects method
2) WOE Method: Minimum Data Requirements			
	-at least ten data points from at least three studies; minimum of each of two soil invertebrate and two crop/plant data points.	None specified – took advantage of the new data generated as part of the PTAC Ecologically Acceptable Endpoints project	At least ten data points from at least three studies are required to perform WoE procedure (including a minimum of 2 soil invertebrate and 2 plant toxicity endpoints)
3) Summary of WoE Method:			
	Ag.. R/P Land Use: 25th %ile of "effects" and "no effects" data = "No Potential Effects Range" (**NPER**). Threshold Effects Conc. (**TEC**) = NPER/uncertainty factor (**UF**) **Commercial & Industrial:** Effects Concentration Low (**ECL**) = 25th %ile of effects data only.	**SSD Method:** *Departures from CCME (1996) WoE method:* 1) Only effects-endpoints (ECx or LCx) used; 2) NOEC and LOEC data were not used if corresponding ECx data available; 3) Toxicity endpoint response levels standardized at or near the 50% response level for sublethal studies. Where studies provided endpoints that were not based on a 50% response, the ECx value for the data point where	**WoE (SSD) Method:** *Comparison with PHC CWS method* 1) EC25 and LC25 data should be used. If cannot determine these endpoints from the study data, then closest ECx, LCx data point should be used instead. 2) NOEC and LOEC data not recommended for WoE method; however -;

	CCME (1996)	PHC CWS	CCME (2005)
		‘x’ was the closest to 50% was used; 4) For the same species, individual toxicity data points were considered to be redundant if they (i) represented different response levels for the same type of response and under the same or highly similar exposure conditions; (ii) were for different soil types, but the objective was not to evaluate effects of soil properties; or (iii) were based on different response measures which are known to be directly, causally connected. 5) For data points deemed to be redundant, a single composite response concentration was calculated as the geometric mean; 6) For toxicity data for the same species, response type, response level and exposure conditions, but based on different exposure periods, the data for the longer exposure period were given precedence; 7) Separate analyses of the plant and soil invertebrate data sets carried out; 8) 25th %ile of the combined effects data	“If insufficient IC25 and EC25 data are available and these values cannot be derived from the dose-response curves, then the combined set of “effects” and “no observed effects” data can be used instead.” (as for 1996 protocol). 3) Tox endpoint response level standardized at or near 25%, with allowances for use of data when this cannot be achieved. 4) “Data points for the same species that are redundant should be combined into a single composite response concentration calculated as the geometric mean of the individual values. Individual toxicity data points are considered redundant if they: • represent different response levels for the same type of response under the same or highly similar exposure conditions; or, • were based on different response data which are known to be directly, causally connected (e.g., plant wet weight and dry weight).” 6) For toxicity data for the same species, response type, response

	CCME (1996)	PHC CWS	CCME (2005)
		(EC/LC50) set for soil invertebrates and plants used to derive a SQG for agricultural and residential/parkland sites (similar to the protocol for application of an Effects Concentration - Low (EC-L) CCME (1996) protocol); 9) 50th &ile of the plant effects (not mortality) data used to derive a soil quality benchmark for commercial and industrial land uses.	level and exposure conditions, but based on different exposure periods, the data for the longer exposure period were given precedence; 7) Separate analyses of the plant and soil invertebrate data sets carried out (same as PHC CWS) 8) The 25th %ile of the rank distribution, identified as the "estimated species sensitivity distribution – 25th percentile" (**ESSD25**), is used as the basis for soil contact guidelines for the agricultural and residential/parkland land uses. *And* TEC = ESSD25/UF. • 1 < UF < 5 • magnitude depends on – o whether only minimum data requirements are met or more than minimum o <> 3 taxonomic groups represented o whether SSD for plants and animals is very dissimilar (i.e. if > 50% of data for either soil or plant SSD is lower than 25th %ile of combined data set. o Short –term vs chronic data

	CCME (1996)	PHC CWS	CCME (2005)
			available o > 50% of data points depend on test conditions likely to lead to low bioavailability. 9) The 50th %tile of this distribution, identified as the "estimated species sensitivity distribution– 50th percentile" (**ESSD50**), is used as the basis for soil contact guidelines for the commercial and industrial land uses. *And* ECL = ESSD50.
4) LOEC Method: Minimum data requirements-			
		Not applicable	Minimum of three studies reporting LOEC values
5) Summary of LOEC Method			
	Ag.. R/P Land Use: TEC = Lowest LOEC/UF Commercial & Industrial: ECL = geometric mean of available LOECs (assumes log-normal SSD)	Not applicable	Same as CCME (1996) 1 < UF < 5 "If expert judgement determines that an UF is warranted for the calculation of the TEC, the following criteria should be used as a guide for application to determine an UF between one and five: • The LOEC is considered "biologically significant" and not just statistically different from controls, and therefore extrapolation below this level of

	CCME (1996)	PHC CWS	CCME (2005)
			effect is required. • The LOEC is taken from an acute lethal or sublethal study. • Only the minimum number of studies (three) was available to select the lowest LOEC. • Fewer than three taxonomic orders are represented when selecting the lowest LOEC.”
6) Median Effects Method: minimum data requirements -			
		Not applicable	≥ 3studies must be considered to select the lowest EC50 or LC50, including one terrestrial plant, and one soil invertebrate study.
7) Summary of Median Effects Method:			
	Ag.. R/P Land Use: TEC = lowest available EC50 or LC50/UF; UF in range of 5 to 10. Commercial & Industrial: Method not recommended for derivation of SQG_E for commercial or industrial land uses.	Not applicable	Same as CCME (1996) If lowest datum is EC50 , then UF = 5 should be initially applied to derive the TEC. If lowest datum is LC50, then UF = 10 should initially be applied. Selection of UFs is based on median acute/chronic ratios determined for EC50 and LC50 data versus NOEC data for 38 inorganic and organic contaminants for soil-dependent organisms (Bonnell, 1992).

	CCME (1996)	PHC CWS	CCME (2005)
			Uncertainty factors of 5 and 10 have also been proposed for use in deriving guidelines for soil from short-term data (Dennemen and van Gestel, 1990; van de Meent, 1990; van der Berg and Roels, 1991). An additional UF factor between one and five may be applied if points two, three, or four listed in the LOEC method for UF selection are incurred.
8) Provisional Methods			
	When data requirements for one of the three primary methods not met, can develop a SQGE using relaxed requirements coupled with professional judgement. Provisional methods can be used to reduce SQG relative to 1991 interim soil quality criteria, but not to increase value.	Not applicable	No provision for provisional methods: "If minimum data requirements for the above methods cannot be met, then there is insufficient information to develop a final environmental soil quality guideline (SQGE). Data gaps will be identified for further research."
9) Tox Data Screening Guidance			
		Not discussed in detail. The objective was to critically evaluate as much data as possible and bring it to bear, given the limited amount of available scientific information for deriving a new set of standards.	**Bioassay test procedures** should conform to currently acknowledged and accepted soil toxicity testing practices or protocols (e.g., Environment Canada, 2004a, 2004b, 2004c; OECD, 1984, 1993; Green et al., 1989; ASTM, 1996, 1990a, 1990b; ISO, 1999; ISO, 1998, 1991, 1992). Data generated using non-standardized testing procedures

	CCME (1996)	PHC CWS	CCME (2005)
			should be evaluated case-by-case. Exposure time and recognized toxicological endpoints (e.g., mortality, reproduction, growth) for soil contaminants must be identified. Environmental test conditions (e.g., soil type, pH, organic matter and clay content, moisture content, temperature, etc.) should be recorded so that factors affecting contaminant availability and toxicity can be evaluated. Appropriate statistical analysis should be performed and reported in the study. Tests that measure contaminant soil toxicity in combination with other conditions considered to be environmental stressors to the test organism (e.g., soil temperature changes), can be used provided that these stressors have been accounted for in the test design. Experimental effect must be attributable to contaminant of concern (avoid contaminant mixtures, such as sludges, unless clearly evident that the effect is due to the contaminant

	CCME (1996)	PHC CWS	CCME (2005)
			of concern). Studies which report measured values of contaminants in the soil must use comparable analytical methods for use in the derivation process, and should report an actual exposure concentration, not just an applied concentration (especially for volatile chemicals). **Field Data:** Can be used under certain circumstances.
10) Soil Types:			
		Fine-grained CWS developed from toxicity data on primarily coarse-grained soils (or what were thought to be coarse grained soils at the time) using simple administrative rules intended to reflect strength of sorption to soil surface area, partititioning between soils and soil vapour or interstitial water, and potential for absorption vs adsorption. (i.e. – **Professional Judgement**)	Where sufficient data exist, coarse-grained and fine-grained soils should be considered separately, and guidelines developed for each soil type. " Possible solutions may include: • Data for the two soil types can be combined, and the resulting guideline applied for both soil types. • A soil contact guideline can be developed for a soil type for which sufficient data are available. This guideline can be applied to the other soil type as a provisional guideline. • A soil contact guideline can be developed for a soil type for which sufficient data are available, and the

	CCME (1996)	PHC CWS	CCME (2005)
			guideline adjusted for the other soil type by a factor determined by professional judgement. This factor could be based on toxicity studies for the chemical that consider the effects of soil type, or on the behaviour of similar chemicals. The resulting soil contact guideline would be considered a provisional guideline.”
11) Bioavailability			
		Detailed discussion regarding aging and bioavailability in Appendix D of Scientific Rationale Document. Concluded that site-specific bioavailability adjustments not feasible at this time.	“…in some cases the data may reflect only a limited range of conditions, or be biased towards data from a particular soil. It is anticipated that, in most cases, data are likely to be biased towards conditions of relatively high bioavailability. However, in some cases data may be biased towards conditions of relatively low bioavailability; this could lead to the development of a soil contact guideline which is not protective of most Canadian sites. **Therefore, the bioavailability conditions for toxicity studies used to develop the soil contact guideline should be evaluated**.”

Three methods have been available since the 1996 guidance for deriving an ecological soil contact guideline: (i) a Weight-of-Evidence (**WoE**) approach; (ii) Lowest LOEC method; and (iii) Median Effects method. Of these, the WoE method has been revised most extensively, and is most relevant to the PHC CWS ecological soil contact numerical guidelines.

Currently, the majority of petroleum hydrocarbon contaminated sites in Canada are remediated through application of generic numerical (Tier 1) standards. This is often ascribed to the fact that use of generic standards, as opposed to site-specific approaches, allows for more rapid regulatory approval, as well as better acceptance of the result by third parties such as purchasers, lease holders, financial institutions and the general public. Moreover, there are currently no approved Tier 2 approaches available for the direct ecological (eco) soil contact pathway.

The PHC CWS tables of numerical generic standards include 64 possible combinations of contaminant type, land use designation, soil type, and groundwater conditions. For 34 of these 64 combinations, the most stringent numerical soil assessment and remediation guideline is the ecological direct contact guideline value. Given the number of PHC contaminated sites in Canada, the specific value of the generic soil standards for ecological direct contact are expected to have a large bearing on remediation efforts, especially if more site-specific (Tier 2/3) approaches do not become more acceptable.

Table 4-2 expands on the comparison in Table 4-1 by briefly describing implications of applying the CCME (2000) methodology versus the proposed CCME (2005-draft) derivation protocols.

Table 4-2: Implications of the Different Derivation Protocols

Key Issue	CCME 2000	CCME 2005	Implications vs CCME 2000 (assuming ecotoxicity same data set)
Preferred Method	Weight of Evidence (WOE)	Weight of Evidence if sufficient data (can include NOEC if insufficient EC25)	**None.** There are likely sufficient data to use WOE per CCME 2005
Data Redundancy	Rules exist	Similar rules	**None**
Use of EC25 vs EC50 for individual data points when constructing ESSD (Estimated Species Sensitivity Distribution)	EC50	EC25	**Factor of 2-10+ reduction:** • factor of 1.5-2.5 with mogas and alfalfa, barley (ESG, Mar 2000, Table H-1) • factor of 2.5 with naphthalene and barley (ESG, Mar 2000, Fig 8) • factor of 2 - 10+ with BTEX and wheatgrass (ESG, June 2001, Table B2-B4)
Method of calculating Standard for Ag/Res/Park lands	25%ile of combined effects data for invertebrates and plants	25%ile of combined effects data for invertebrates and plants. UF applied	**Factor of 1-5 reduction depending on UF** (function of amount of data available for WOE approach)
Method of calculating Standard for Comm/Ind lands	50%ile of effects data for plants	50%ile of combined effects data for invertebrates and plants.	**Factor of approx 1.1 - 1.3 reduction** (eg Figs 4.9, 4.10,4.11 of CWS Rationale)
Tox Data Screening Guidance	Not discussed in detail	Yes	**None?**
Soil Type	Data was from primarily coarse grained soils. Professional Judgement used for fine grained	Various options including professional judgement	**None if similar judgement used**
Method of calculating Standard for Ag/Res/Park lands	25%ile of combined effects data for invertebrates and plants	25%ile of combined effects data for invertebrates and plants. UF applied	**Factor of 1-5 reduction depending on UF** (function of amount of data available for WOE approach)
Bioavailability Adjustments	Not feasible at the time	Should be evaluated	**Not feasible for Tier 1?**

4.2 Re-evaluation of soil quality guidelines for Fractions F1 and F2 in surface soils, including fine- versus coarse-grained

4.2.1 Introduction

The overarching considerations for the recommendations of F1 and F2 ecological soil contact guidelines (criteria) were to provide a level of environmental protection that varies with the protection goals sought for individual land use categories. The level of required ecological functioning and the appropriate level of protection of key ecological receptors specific to the individual land use designations are described in Section 3.

The EcoSG commissioned a study to review the data from relevant toxicity data sources with the desire to derive F1 and F2 eco soil contact criteria appropriate for each of the land use designations that reflect the need for the appropriate level of protection of key ecological receptors, and which would also result in the derivation of eco soil contact criteria which are neither overly or inadequately protective. All known relevant toxicity data for Fractions 1 and 2 were collected and compiled, including the median (50%) and 25% effects levels, as well as general information regarding the testing protocol and noted results.

The commissioned study's methodology, findings, summary and recommendations are presented in the report (Cermak and Tindal, 2006) and included as Appendix E. It should be noted, however, that additional data interpretations and suggested derivation approaches that were not considered or provided in the commissioned study report are included in Section 4.2.

The approaches were used for deriving draft F1 and F2 eco soil contact guidelines were:

1. CCME (2000): The ecotoxicity data were analyzed following the approach used for the derivation of the original PHC CWS values. The agricultural/residential criterion was calculated as the 25th percentile of the combined plant and invertebrate LC/IC50 dataset. The commercial/industrial criterion was calculated as the 50th percentile of the plant only IC50 dataset.

2. CCME (2005): The new CCME draft guidance proposes deriving soil guidelines based on the 25% effect level (CCME 2005). The agricultural/residential and the commercial/industrial criteria were calculated as the 25th and 50th percentiles, respectively, of the combined plant and invertebrate LC/IC25 dataset (i.e., ESSD25 and ESSD50, respectively).

3. Alternative Hybrid Methodologies:

   - An alternative method was suggested at the November 21, 2005 meeting of the EcoSG in Toronto, Ontario. A combined dataset consisting of IC25 plant and LC/EC50 invertebrate data was used. The agricultural/residential and the commercial/industrial criteria were calculated as the 25th and 50th percentiles, respectively, of this combined dataset. The rationale for this hybrid was based on the premise that, while a functioning soil invertebrate community is assumed to be important for plant growth in an agronomic, residential garden, or parkland-type setting, commercial and industrial landscapes tended to be intensively managed, and the development of plantings and landscapes for aesthetic purposes relies more on active management, including fertilization and soil amendments, than processes undertaken by soil invertebrates.

- Plant growth may be important at commercial/industrial (C/I) land use sites, but a terrestrial ecosystem that supports entirely uninhibited functioning of soil invertebrates may not be warranted. As such, C/I criteria values were calculated using the 50th percentile of the plant-only, IC25 data.
- Where data may have been limiting for either/or coarse- and fine-grained soil, the data sets were combined.
- It was recognized during the F1 and F2 data compilation and analysis that in many cases the 25% TEC estimated from the ecotoxicity data were below the lowest concentration tested because the experiment was not designed for the accurate determination of low effect levels. Professional judgment was needed to decide whether the data set was used and in some instances, the data were excluded. In other instances, LC25 for invertebrate mortality could not be estimated from the data (Cermak and Tindal, 2006 - Appendix E). This resulted in an overall reduction of the data set used for the CCME (2005) determinations, and in the case of the F1 derivation, resulted in the data set failing to meet the minimal data requirements. As such, alternative derivation was considered which included incorporation of F1 data (over use of mogas) and also, use of LOEC/NOEC data to increase the size of the data set, consistent with the approach described in CCME (2005).

4.2.2 Fraction 1

Two studies on the ecotoxicity of Fraction 1 and two studies on the ecotoxicity of motor gasoline (mogas), as a surrogate for Fraction 1, were found (Cermak and Tindal, 2006; Appendix E). The Fraction 1 data were new and not previously used in the derivation of the PHC CWS (CCME 2000). There were insufficient data to derive soil quality criteria for Fraction 1, therefore, data on the ecotoxicity of mogas were also used to estimate Fraction 1 criteria (Cermak and Tindal, 2006; Appendix E).

Mogas is a distillate that may contain significant portions of petroleum hydrocarbon constituents outside of the intended range of F1. In particular, mogas contains some substances that would likely fall within the F2 range. This may be important since: 1) these generally higher molecular weight (MW) substances may exhibit a different toxicity than for F1 constituents; and, 2) higher MW PHC constituents may exhibit substantially different environmental fate, especially in regards to volatility and environmental persistence. As such, the use of mogas data to manage environmental PHC releases of F1 quantified using CCME or comparable methods may result in inaccurate predictions of risk. Use of toxicity data developed using a mixture that is more consistent with what is being analyzed as F1 by the CCME method is clearly preferable to the extent possible; although the extent to which a single F1 mixture adequately represents the F1 toxicity for other possible release types may be questionable.

The EcoSG endorsed the proposed use of mogas data only in those instances where similar quality toxicity data for F1 do not exist. This resultant data set met the minimum requirements for a WOE determination (CCME 2005). Details of the approach and the data set are presented in Appendix F. The corresponding derived criteria are presented as 2005 in the following Table 4.2-A.1.

Table 4.2-A.1: Guideline Values for F1 Surface Soils - Combined F1/Mogas Data

	Fine Soil[3]		Coarse Soil	
	Ag/Res (mg/kg)	Com/Ind (mg/kg)	Ag/Res (mg/kg)	Com/Ind (mg/kg)
Existing Guideline: CCME (2000)[1]	**260**	**660**	**130**	**330**
Guidelines Based on CCME (2005) Methodology[2]	**210**	**320**	**210**	**320**

ag/res = agricultural/residential
com/ind = commercial/industrial

1. CCME 2000 methodology uses a distribution of IC/LC50 data, and uses the 25th percentile of the combined plants and invertebrate dataset for ag/res, and the 50th percentile of the plants-only dataset for com/ind.
2. CCME 2005 methodology uses a distribution of IC/LC25 (or 20) data, and uses the 25th percentile of the combined plants and invertebrate dataset for ag/res, and the 50th percentile of the combined plants and invertebrate dataset for com/ind. Preference given to Fraction F1 data; if no data for Fraction 1 available, then mogas data used.
3. No significant difference was observed between the toxicity of mogas in coarse- and fine-grained soils. Therefore, it was recommended by Cermak and Tindal (2006, Appendix E) that the same criteria be used for both coarse- and fine-textured soils.

The committee also considered several alternates to the CCME 2005 recommended approach; adoption of any of these is a policy decision on the part of the SQGTG. Their values are presented in Table 4.2-A.2. The basis for derivation, and science justification are as follows. For the Hybrid Methodology, the rationale is that while a functioning soil invertebrate community is assumed to be important for plant growth in an agronomic, residential garden, or parkland-type setting, commercial and industrial landscapes tended to be intensively managed, and the development of plantings and landscapes for aesthetic purposes relied more on active management, including fertilization and soil amendments, than processes undertaken by soil invertebrates.

Table 4.2-A.2: Policy-based Guideline Values for F1 Surface Soils - Combined F1/Mogas Data

	Fine Soil[1]		Coarse Soil	
	Ag/Res	Com/Ind	Ag/Res	Com/Ind
	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)
Guidelines Based on Hybrid Methodology[2]	**260**	**380**	**260**	**380**
Guidelines Based on modified CCME (2000) Methodology-Revisited[3]	**410**	**620**	**410**	**620**
Guidelines Based on CCME (2000) Methodology - Revisited[4]	**410**	**670**	**410**	**670**

1. No significant difference was observed between the toxicity of mogas in coarse- and fine-grained soils. Therefore, it was recommended by Cermak and Tindal (2006, Appendix E) that the same criteria be used for both coarse- and fine-textured soils.

2. Hybrid methodology uses a distribution of IC/EC/LC25 data for plants and IC/EC/LC50 for invertebrates, combined into one data set. It then uses the 25th percentile of the combined dataset for ag/res, and the 50th percentile of the combined data set for com/ind.

Preference given to fraction F1 data; if no data for Fraction F1 available, then mogas data used instead.

3. Modified CCME 2000-Revisited methodology uses a distribution of IC/EC/LC50 data, and uses the 25th percentile of the combined IC/LC/EC50 plants and invertebrate endpoints dataset for ag/res, and the 50th percentile of the combined IC/EC/LC50 plants and invertebrate endpoints dataset for com/ind. Preference given to Fraction F1 data; if no data for Fraction 1 available, then mogas data used.
4. CCME 2000 methodology-revisited uses a distribution of IC/EC//LC50 data, and uses the 25th percentile of the combined plants and invertebrate dataset for ag/res, and the 50th percentile of the plants-only data set for com/ind.

Species sensitivity distributions (SSDs) were constructed in the Cermak and Tindal (2006, Appendix E) study, including and excluding the acute toxicity data for corn and red fescue, and criteria specifically using only the mogas data were subsequently derived. Overall, all data sets in Cermak and Tindal (2006, Appendix E) met the minimum requirements for the number of data points (minimum of ten). However, the data sets from Cermak and Tindal (2006, Appendix E), based on low effect concentrations (i.e., LC/EC/IC25), did not meet the requirements for the minimum number of species since data from only one invertebrate species were available. An IC25 was only available for one invertebrate species (*O. folsomi*); but, data from two species are required for CCME 2005 guideline derivation.

As per the CCME 2005 approach recommendations, the NOECs and LOECs for *Eisenia andrei* reproduction, as provided in ESG (2000), were used and using only the mogas data set. A NOEC and LOEC were available from two tests; therefore, the geometric mean of all of the NOEC and LOEC data was taken to reduce redundancy in the mogas data set. Using this new data set that included data on the toxicity of mogas to *E. andrei*, species sensitivity plots were constructed (Cermak and Tindal, 2006; Appendix E).This resulted in the data set meeting the minimal requirements for both the number of data points and the number of species. Inclusion of the *E. andrei* data changed the soil quality criterion for agricultural/residential land-uses minimally from those originally presented in the Cermak and Tindal report (2006, Appendix E), and did not affect the criterion for commercial/industrial land uses. Since the majority of the data used in the derivation were EC/IC(20)25s (17 out of 18 data points), the use of an uncertainty factor to account for the use of NOEC and LOEC data was considered unnecessary (Cermak and Tindal, 2006; Appendix E).

The majority of the mogas ecotoxicity data were for coarse-textured soils. No significant difference was observed between the toxicity of mogas in coarse- and fine-textured soils. Therefore, it was recommended by Cermak and Tindal (2006, Appendix E) that the same criteria be used for both coarse- and fine-textured soils.

4.2.3 Fraction 2

Three studies on the ecotoxicity of Fraction 2 to soil organisms were found. The majority of the data were used in the original derivation of the PHC CWS. Very few new fraction-specific data were found.

Most of the data were from tests conducted in a fine-grained, Chernozem soil. During the original derivation of the PHC CWS, the Chernozem soil was erroneously classified as a coarse-textured soil instead of a fine-textured soil. Therefore, the soil criteria for fine-textured soils derived in Cermak and Tindal 2006 (Appendix E) are lower than those originally derived in the current PHC CWS (CCME 2000), but similar to the PHC CWS values for coarse-grained soils.

In terms of the Fraction 2 toxicity data and for certain endpoints, an LC/EC/IC25 value could not be determined. These included two acute lethality tests with *E. andrei* in fine-textured soil, one acute lethality test with *E. andrei* in coarse-textured soil, and one acute lethality test each for *L. terrestris* and *O. folsomi* in fine- and coarse-textured soils. Inclusion of this data was not required in order to meet the CCME (2005) minimal data requirements for the derivation of soil quality criteria (Cermak and Tindal, 2006; Appendix E).

Four plant IC20s were below the lowest concentration tested. One was from an alfalfa definitive test (shoot dry weight), and three were from a northern wheatgrass definitive test (root length, and root wet and dry weight). The alfalfa IC20 was very close to the lowest concentration tested and therefore was included in the data set as it was considered to be a reasonable estimate.

There were insufficient data for the derivation of criteria for coarse-textured soils. There was no consistent difference between the ecotoxicity of Fraction 2 in fine- as compared to coarse-textured soils; in fact, Fraction 2 appeared to be slightly more toxic in fine-textured soils (lower LC/IC50 values). Thus, the data do not support the hypothesis that petroleum hydrocarbons should have a lower toxicity in fine-grained soil. The criteria derived for Fraction 2 in fine-textured soils are provided in the following Table 4.2-B.1. Further evaluation is warranted to assess whether the values of coarse-grained soil guidelines warrant any change from the existing CCME (2000) guidelines or from the fine-grained soil values presented in Table 4.2B.1.

Table 4.2-B.1: Re-derived Guideline Values for F2 Surface Soils

	Fine Soil		**Coarse Soil**	
	Ag/Res (mg/kg)	**Com/Ind** (mg/kg)	**Ag/Res** (mg/kg)	**Com/Ind** (mg/kg)
Existing Guideline: CCME (2000)[1]	**900**	**1500**	**450**	**760**
Guidelines Based on CCME (2005) Methodology[2]	**150**	**260**	**nd**	**nd**

nd = not determined. Insufficient data for derivation of coarse-grained soil; na = not applicable; ag/res = agricultural/residential; com/ind = commercial/industrial

1. CCME 2000 methodology uses a distribution of IC/EC/LC50 data, and uses the 25th percentile of the combined plants and invertebrate dataset for ag/res, and the 50th percentile of the plants-only data set for com/ind.
2. CCME 2005 methodology uses a distribution of IC/EC/LC25 (or 20) data, and uses the 25th percentile of the combined plants and invertebrate dataset for ag/res, and the 50th percentile of the combined plants and invertebrate dataset for com/ind.

In addition (as for F1), the SQGTG is asked to deliberate on the further consideration of use of plant-only (IC20) data and also hybrid approach data (i.e., plant LC/IC20, and invertebrate LC/EC50 data) for numerical standards for commercial and industrial land uses. This option would increase F2 numbers relative to provided above; i.e. 230 mg/kg for plant-only and 280 mg/kg for hybrid approach, and for both fine and coarse-textured soils (Table 4.2-B.2). The technical rationale for acceptance of this option remains the same as for the original derivation.

Table 4.2-B.2: Policy-based Guideline Values for F2 Surface Soils

	Fine Soil		Coarse Soil	
	Ag/Res	**Com/Ind**	**Ag/Res**	**Com/Ind**
	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)
Guidelines Based on Hybrid Methodology [1]	**180**	**320**	**nd**	**nd**
Commercial/Industrial Guideline Based on 50th percentile of 25%Plant-only Effects Data[2]	**na**	**300**	**na**	**nd**
Guidelines Based on CCME (2000) Methodology-Revisited[3]	**390**	**980**	**nd**	**nd**

1. Hybrid methodology uses a distribution of IC/EC/LC25 data for plants and IC/EC/LC50 for invertebrates, combined into one data set. It then uses the 25th percentile of the combined dataset for ag/res, and the 50th percentile of the combined data set for com/ind.
2. Used available LC/IC20(25) plant effects, acute and chronic data. See Figure 3 in Cermak and Tindal, 2006 (Appendix E)
3. CCME 2000-Revisited methodology uses a distribution of IC/LC/EC50) data, and uses the 25th percentile of the combined plants and invertebrate dataset for ag/res, and the 50th percentile of the plant-only data set for com/ind..

nd = not determined. Insufficient data for derivation of coarse-grained soil
na = not applicable
ag/res = agricultural/residential
com/ind = commercial/industrial

1. *CCME 2000 methodology uses a distribution of IC/EC//LC50 data, and uses the 25th percentile of the combined plants and invertebrate dataset for ag/res, and the 50th percentile of the plants-only data set for com/ind.*
2. *CCME 2005 methodology uses a distribution of IC/EC/LC25 (or 20) data, and uses the 25th percentile of the combined plants and invertebrate dataset for ag/res, and the 50th percentile of the combined plants and invertebrate dataset for com/ind.*
3. *Hybrid methodology uses a distribution of IC/EC/LC25 data for plants and IC/EC/LC50 for invertebrates, combined into one data set. It then uses the 25th percentile of the combined dataset for ag/res, and the 50th percentile of the combined data set for com/ind.*
4. *CCME 2000-Revisited methodology uses a distribution of IC/LC/EC50) data, and uses the 25th percentile of the combined plants and invertebrate dataset for ag/res, and the 50th percentile of the plant-only data set for com/ind.*
5. *Used available LC/IC20(25) plant effects, acute and chronic data. See Figure 3 in Cermak and Tindal, 2006 (Appendix E)*

4.3 Re-evaluation of Soil Quality Guidelines for Fractions F3 and F4 in Surface Soils

4.3.1 Introduction

This section examines the existing soil quality guidelines for F3 and F4 for the eco soil contact pathway in light of new ecotoxicity data that have become available since the derivation of the existing guidelines. In addition, we make recommendations to update the existing guidelines where appropriate. A resource document, generated under CCME contract 378-2006, is available (Tindal, Visser, and Cermak, 2005; Appendix C) and provides more detail on the issues presented in this section.

4.3.2 Existing F3 and F4 Guideline Values and Basis

The existing eco soil contact guidelines for F3 and F4 are summarized in Table 4.3-A.

Table 4.3-A. Existing Eco Soil Contact Guideline Values for F3 and F4

	Fine Soil		Coarse Soil	
PHC Fraction	Ag/Res[1] (mg/kg)	Com/Ind[2] (mg/kg)	Ag/Res[1] (mg/kg)	Com/Ind[2] (mg/kg)
F3	800	2,500	400	1,700
F4	5,600	6,600	2,800	3,300

1. *agricultural and residential land uses*
2. *commercial and industrial land uses*

The existing guidelines for F3 were calculated based on a species sensitivity distribution of 50th percentile (IC/EC/LC$_{50}$) F3 ecotoxicity data generated specifically for the PHC CWS (reported in ESG, 2003). Redundant data were removed or combined based on protocols in CCME (2000). The departure point for guideline development was the 25th percentile of the combined plants and invertebrate dataset for agricultural/residential land use, and the 50th percentile of the plants-only dataset for commercial/industrial. From the respective points of departure for each land use, the coarse soil guidelines were calculated by applying a factor of 0.31 to account for the apparent analytical recovery of F3 from soils and the fine soil guidelines were calculated by applying a factor of 2 to the coarse soil guidelines, and applying an upset limit of 2,500 mg/kg.

The existing F4 guidelines were calculated based on ecotoxicity data for whole federated crude (data for the F4 cut were not available at the time of derivation) and by making conservative assumptions about the contribution of F4 to whole-product toxicity. Similar guideline derivation procedures to those described above for F3 were employed, with the species sensitivity distribution again being based on 50th percentile effects data.

4.3.3 New F3 and F4 Ecotoxicological Data

New ecotoxicological data for F3 and F4, are summarized below, together with brief comments on the scope of each and any challenges with incorporating the new data with existing data.

Multi-Concentration Studies

Multi-concentration studies are conventional toxicity tests exposing organisms to multiple concentrations of a toxicant to enable response levels such as IC_{25} and IC_{50} to be calculated.

Canada-Wide Standards for Petroleum Hydrocarbons (PHCs) in Soil: Scientific Rationale, CCME (2000). This is the document containing the original derivation of the soil eco contact guidelines. Most of the ecotoxicity data used in the derivation were obtained with a black Chernozem (fine textured) soil. The data were for freshly spiked hydrocarbon fractions. The Sub-Group had reservations about three aspects of this work:

(i) the guidelines are based on chemical analyses that did not use the PHC CWS reference analytical method (CCME, 2001), and based on a significant weight of evidence from more recent analytical work (e.g., Axiom, 2005b), the Sub-Group felt that the 31% analytical recovery used in the guideline calculations was likely too low;

(ii) the Sub-Group did not support the factor of 2 used to estimate fine soil guidelines from coarse soil, since the F3 and F4 guidelines were primarily based on fine soil data; and,

(iii) the Sub-Group had concerns about the fact that some of the toxicological values used in the guideline derivation were well below the lowest test concentration used, indicating a very significant uncertainty with these values (e.g., an IC_{50} for northern wheatgrass shoot wet weight of 610 mg/kg, based on a test where the lowest concentration used was 5,000 mg/kg). The uncertainty associated with this issue gets even greater if the IC_{25} effect level is used.

Toxicity of Petroleum Hydrocarbons to Soil Organisms and the Effects on Soil Quality: Phase I Fraction-Specific Toxicity of Crude Oil., ESG (2003). This document provides background information on the ecotoxicity data used in CCME (2000), and in addition includes ecotoxicity data on F4 that were not available at the time that the CCME (2000) calculations were made. The uncertainties noted above for CCME (2000) also apply to ESG (2003).

Summary of the soil toxicity and soil chemical analysis data for petroleum hydrocarbon fractions 2 and 3, (Cermak et al., 2005). This work is part of a PhD thesis looking into various aspects of PHC uptake and toxicity, and includes some data which are pertinent to the current review. Data are for freshly-spiked hydrocarbon fractions in black Chernozem soil. Strong points of the data in this report include lower exposure concentrations for some of the same species tested in ESG (2003), and hence a reduction in the uncertainty in some endpoints. One drawback of this dataset is that a specialized analytical method was used to measure aliphatic and aromatic hydrocarbons separately, and so some uncertainty remains as to how the measured concentrations would relate to concentrations measured by the PHC CWS reference analytical method.

Ecotoxicity of Hydrocarbon Residuals in Bioremediated Oil-Contaminated Clay Soils, Visser (2005b). This study contributes to the pool of knowledge on F3 PHC ecotoxicity by considering a different soil type (heavy clay). The analytical work was done using the PHC CWS reference analytical method, so the confidence in the analytical values is higher than with the two studies above. In contrast with the two studies above, this study looked at hydrocarbons that had weathered in the lab for a year prior to toxicity testing.

Single Concentration Studies

Single Concentration studies examine the toxicological response at a single concentration (or at a limited number of concentrations). While it is not generally feasible to calculate response levels such as IC_{25} and IC_{50}, these studies are field-based and so are particularly valuable because test conditions have more relevance to typical ecological and agricultural situations than have typical laboratory-based tests.

Toxicity of Petroleum Hydrocarbons to Soil Organisms and the Effects on Soil Quality: Phase 2: Field Studies, Visser et al. (2003). This study tilled federated crude oil into the top 15 cm of test plots set up in fine soil (2 concentrations) and coarse soil (1 concentration), and observed the effects on plants and invertebrates both on a field scale and in lab tests. The data generated are of interest to the current project, since they allow a comparison between response seen in lab tests, and actual ecological communities present in an agricultural setting. Data presented in Visser et al. (2003) include the first 12 months of observations and toxicity tests on the field plots

Toxicity of Petroleum Hydrocarbons to Soil Organisms and the Effects on Soil Quality: Phase 3: Long-term Field Studies, Visser (2005a). This study continues on from Visser et al. (2003), and presents the data from 24 to 36 months after soil spiking. It is particularly relevant to the current review, based on (i) the large number of species/groups considered (15, compared to 6 in the PHC CWS); (ii) the greater relevance of a study conducted in a field setting over lab tests; (iii) the fact that sufficient analytical measurements were collected using the PHC CWS analytical reference method to be able to use that as a basis for data interpretation; and, iv) the fact that the lab data were chronic and the field data represented whole season growth for plants, and long-term populations for invertebrates.

Environmentally Acceptable Endpoints of CCME Canada-Wide Standards (CWS) Petroleum Hydrocarbons Fraction F3 for Weathered Petroleum Hydrocarbons in Soil, Axiom (2005a). This study provided toxicological data for the Visser et al. (2003) and Visser (2005a) fine soil plots five years after spiking, used the PHC CWS analytical reference method, and is useful as a confirmation of the results in Visser (2005a).

4.3.4 CCME (2005) Protocol and Rationale for Departures

The CCME (2005) draft protocol for the derivation of environmental and human health soil quality guidelines is similar in many respects to the protocols used to derive the existing eco soil contact guidelines. The most significant difference (when using the weight of evidence method) is the recommendation to build a species sensitivity distribution from 25^{th} percentile (e.g., IC_{25}) rather than 50^{th} percentile (e.g., IC_{50}) effects data.

Based on the CCME (2005) protocol, the preferred approach to data analysis would be to treat all the available data as a single dataset, remove/combine redundant data, and generate a distribution of non-redundant 25^{th} percentile effect level data. The Sub-Group felt that, in the case of the F3 data, this approach was not appropriate, for the following reasons:

- The three single concentration studies noted above are not amenable to being combined with the other data under the CCME (2005) protocols, and hence to follow the CCME (2005) approach would exclude half of the new studies, including much of the potentially most relevant data.
- The Sub-Group agreed that the 31% recovery used in the CCME (2000) guideline derivation for F3 was likely too low (see Axiom 2005b for additional information), but was unable to reach consensus as to whether changing this recovery factor was justified. Without reasonable confidence in the analytical basis of the CCME (2000) derivations, there was a reluctance to combine this data with the data from other studies.
- The Sub-Group was not confident in combining the results from studies using freshly spiked hydrocarbons fractions (ESG, 2003; Cermak et al., 2005) with the results from studies using weathered hydrocarbons (Visser, 2005b).

The Sub-Group considered the points noted above, and the fact that each of the studies discussed in Section 3.3.3 has points that make it relevant to refining the eco soil contact guidelines for F3, but other issues which make interpretation of the data challenging. The opinion of the Sub-Group, based on discussions at the November 2005 face-to-face meeting in Toronto, was that the most appropriate way forward for F3 was not to attempt to combine all the data in a single distribution, but rather to calculate guideline values for each dataset individually using the substance and spirit of the CCME (2005) protocols as closely as was feasible.

The new data for F4 were analyzed using the CCME (2005) protocol without departures.

4.3.5 Data Analysis

The new multi-concentration studies for F3 were analyzed using three Approaches:

1. the CCME 2005 Approach employs a distribution of IC/LC25 (or 20) data, and uses the 25th percentile of the combined plants and invertebrate dataset for agricultural and residential land use, and the 50th percentile of the combined plants and invertebrate dataset for commercial and industrial land use.
2. the Hybrid Approach applies only to commercial and industrial land use and is based on the CCME (2005) Approach, but uses the 50^{th} percentile of the *plants-only* dataset to derive the commercial and industrial land use guideline.
3. the CCME 2000 Approach uses a distribution of IC/LC50 data, and uses the 25th percentile of the combined plants and invertebrate dataset for agricultural and residential land use, and the 50th percentile of the plants-only dataset for commercial and industrial land use.

The single concentration studies were not amenable to the calculation of IC_{25} or IC_{50} values, since only a single, or very limited number of concentrations were available. Accordingly, a new method was developed for these tests. The "Ranked Response Approach" method may be summarized as follows (full details are available in Tindal, Visser, and Cermak, 2005; Appendix C).

- Data from single concentration studies were presented as the response relative to controls for a range of species/endpoints.
- Redundant data were combined or excluded.
- For each exposure concentration, the non-redundant data were ranked and presented as "Ranked Response Approach" (RRAs).
- Under the CCME (2005) approach, the concentration of hydrocarbon in an RRA was deemed to meet guideline requirements for agricultural/residential land use if the 25th percentile of the RRA showed a response of at least 75% of the control response. Similarly, the level of adverse effects was deemed to be within the level implicit in the definition of the guideline for commercial/industrial land use if the 50th percentile of the RRA showed a response of at least 75% of the control response.
- Under the Hybrid Approach (commercial and industrial land use only) the concentration of hydrocarbon in an RRA was deemed to meet guideline requirements for commercial/industrial land use if the 50th percentile of the RRA *for the plants-only dataset* showed a response of at least 75% of the control response.
- Under the CCME (2000) Approach, the concentration of hydrocarbon in an RRA was deemed to meet guideline requirements for agricultural/residential land use if the 25th percentile of the RRA showed a response of at least 50% of the control response. Similarly, the level of adverse effects was deemed to be within the level implicit in the definition of the guideline for commercial/industrial land use if the 50th percentile of the RRA showed a response of at least 50% of the control response.

As can be seen in Table 4.3-B, in most cases, the RRA method will indicate that the appropriate guideline value is either above or below a certain value.

4.3.5 Recommendations and Rationale

Where possible, guidelines for F3 were calculated for each of the new studies using each of the 3 Approaches noted above (Table 4.3-B). Selection of one of the three Approaches noted above is considered by the Eco Sub-Group to be a policy issue, and is left up to the Soil Quality Guidelines Task Group. Table 4.3-B provides recommended guideline values for F3 under each of the 3 Approaches.

CCME (2005) Approach

Guidelines for each of the new studies calculated using the CCME (2005) Approach are provided in the first block of Table B. Particular weight was given to the Visser (2005a) field study, reflecting i) the greater number of species considered in this study, ii) the fact that this study measured actual crop yields and invertebrate populations in the field; iii) the chronic duration of most of the tests; and iv) the fact that measured analytical concentrations were available that could be tied to results from the CCME reference method with a good degree of confidence. Less confidence was placed on the Cermak et al. (2005) data due to the difficulty in linking the analytical methodology required for that work to standard CCME reference method analyses.

Based on the analysis of Visser (2005a), supported by the weight of evidence from the other studies, the Sub-Group recommends updating the fine soil quality guideline for F3 under agricultural/residential land use from 800 mg/kg to 1,300 mg/kg, and leaving the corresponding guideline for commercial/industrial land use unchanged at 2,500 mg/kg (Table B). It should be noted that the CCME (2000) commercial/industrial guideline value of 2,500 mg/kg was a judgement-based upset limit rather than being derived strictly from toxicological data. It should also be noted that the recommended change to the existing guideline is made on the basis of a 25^{th} percentile effects level (CCME, 2005), and hence uses a more conservative approach than that used to derive the existing guideline values. Further background on this recommendation can be found in Tindal, Visser, and Cermak (2005, Appendix C).

The data available for refining the appropriate guideline value for F3 in coarse soil are much less extensive than those for fine soil. Data in Visser (2005a) suggest that the current guideline for F3 in coarse soils for agricultural/residential land use (400 mg/kg) is protective of plant growth, but may not be protective of all soil invertebrates. The current guideline is protective based on the IC_{50} Approach, but the guideline would need to be less than 330 mg/kg to be protective under the more conservative IC_{25} Approach.

Overall, the Sub-Group recommends updating the F3 guideline in coarse soil for agricultural/residential land use from 400 mg/kg to 300 mg/kg. Insufficient new data are available to recommend any change to the corresponding commercial/industrial guideline of 1,700 mg/kg (Table B). Further background on this recommendation can be found in Tindal, Visser, and Cermak (2005, Appendix C).

Hybrid Approach

Guidelines for each of the new studies calculated using the Hybrid Approach for commercial and industrial land use are provided in the second block of Table 4.3-B. Calculation of F3 guidelines for commercial and industrial land use based on the Hybrid Approach would not result in any change relative to the existing guidelines.

CCME (2000) Approach

Guidelines for each of the new studies calculated using the CCME (2000) approach are provided in the third block of Table 4.3-B. Based on the weight of evidence of these studies, under this Approach, there would be an increase in the guideline values for F3 in fine soil to 2,500 mg/kg for agricultural and residential land use and to 3,600 mg/kg for commercial and industrial land use. No change would arise for the existing guidelines for coarse soil if this Approach were used.

Table 4.3-B. Recommended Changes to Guideline Values for F3

	Guideline Values Indicated from Each Study			
	Fine Soil		Coarse Soil	
Study	**Ag/Res** (mg/kg)	**Com/Ind** (mg/kg)	**Ag/Res** (mg/kg)	**Com/Ind** (mg/kg)
Existing Guideline: CCME (2000)[1]	**800**	**2,500**	**400**	**1,700**
Guidelines Based on CCME (2005) Methodology[2]				
Cermak et al. (2005)[4]	1,000	3,200	nd	nd
Visser (2005b) (Clay Study)	2,300	2,900	nd	nd
Visser et al. (2003) (Phase 2 Field Studies)	1,500	>3,100	<1,100	<1,100
Visser (2005a) (Phase 3 Field Studies)	>1,300	>2,500	<330	>390
Axiom (2005a)	>2,500	>2,500	nd	nd
Recommended Guideline	**1,300**	**2,500**	**300**	**1,700**
Commercial/Industrial Guidelines Based on Hybrid Methodology[3]				
Cermak et al. (2005)[4]	na	5,100	na	nd
Visser (2005b) (Clay Study)	na	2,900	na	nd
Visser et al. (2003) (Phase 2 Field Studies)	na	>3,100	na	>1,100
Visser (2005a) (Phase 3 Field Studies)	na	>2,500	na	>390
Axiom (2005a)	na	>2,500	na	nd
Recommended Guideline	**na**	**2,500**	**na**	**1,700**
Guidelines Based on CCME (2000) Methodology[1]				
Cermak et al. (2005)[4]	2,500	16,000	nd	nd
Visser (2005b) (Clay Study)	3,400	3,600	nd	nd
Visser et al. (2003) (Phase 2 Field Studies)	>3,100	>3,100	<1,100	>1,100
Visser (2005a) (Phase 3 Field Studies)	>2,500	>2,500	>390	>390
Axiom (2005a)	>2,500	>2,500	nd	nd
Recommended Guideline	**2,500**	**3,600**	**400**	**1,700**

Notes:
na = not applicable
nd = no data or insufficient data
ag/res = agricultural/residential
com/ind = commercial/industrial

1. *CCME 2000 methodology uses a distribution of IC/LC50 data, and uses the 25th percentile of the combined plants and invertebrate dataset for ag/res, and the 50th percentile of the plants-only dataset for com/ind.*
2. *CCME 2005 methodology uses a distribution of IC/LC25 (or 20) data, and uses the 25th percentile of the combined plants and invertebrate dataset for ag/res, and the 50th percentile of the combined plants and invertebrate dataset for com/ind.*
3. *Hybrid methodology uses a distribution of IC/LC25 (or 20) data, and uses the 25th percentile of the combined plants and invertebrate dataset for ag/res, and the 50th percentile of the plants-only dataset for com/ind.*
4. *note uncertainty in extrapolating measured hydrocarbon concentrations compatible with the CCME reference method.*

Recommended changes to existing guideline values are highlighted in ***red****.*

Fraction F4

Existing PHC CWS guidelines for F4 were calculated by extrapolation from the toxicity of whole crude oil. In this report, guideline values are calculated for F4 in fine soil, based on F4 ecotoxicity data that were not available at the time of the original derivation. The values calculated using the IC_{25} method were 4,900 mg/kg, and 8,300 mg/kg for agricultural/residential and commercial/industrial, respectively. These guidelines are essentially consistent with the existing guidelines for F4 for fine soil, and no changes to the existing guidelines for F4 are proposed.

4.4 Soil assessment and remediation guidance for deeper versus more shallow soils

4.4.1 Background

The 2000 PHC CWS contained tables entitled "Generic Levels for PHC in Fine/Coarse-Grained Subsoil (>1.5 m depth)". The Sub-Group recognizes that these generic benchmarks offer a site-owner and/or practitioner an alternate set of protective standards without need for a detailed quantitative site-specific risk assessment. This is particularly relevant for the soil contact pathway, as no approved Tier 2/3 protocol is currently available (see recommendations in Chapter 5, however).

The subgroup also recognizes that all provincial jurisdictions except Quebec currently offer some form of generic subsoil criteria. The administrative framework (e.g., conditional or unconditional closure, registration on title, designated "no dig" zones, monitoring) varies between provinces, as does the basis for derivation and application of subsurface guidelines and standards. The subgroup agreed to re-evaluate the subsoil levels on a technical/scientific basis only, recognizing that the administrative framework remains the responsibility of the individual provinces and territories.

4.4.2 Review of CCME (2000) Derivation

The basis for the original derivation was outlined in a memorandum entitled "Conditional Application of Generic Subsoil Remediation Levels in the PHC CWS" (Ted Nason, May 9, 2000). For the eco contact pathway, the following was stated:

> "Very deep-rooted species may explore soil to this depth (1.5 m). Also, certain invertebrates may migrate deeply to avoid moisture stress periodically. In the former case, proportion of root biomass involved is minor; in the latter, proportion of time spent at depth is small. Given the present reliance on fresh product ecotoxicity data, which provide a conservative estimate of biological response, a five-fold increment in the Tier 1 value for surface soil should be protective of the ecological functions at depth".

Another idea considered at the time is that hydrocarbon-affected subsoil could be brought to surface by excavation and be mixed or amended with better quality soil, e.g. topsoil. Based on professional judgement, a 2- to 3-fold reduction in hydrocarbon concentration was assumed in the resulting top soil, as a result of mixing and loss processes. Although this excavation scenario is technically reasonable, it's application within provincial frameworks can be confusing. The derivation contemplates an unconditional closure, in that bringing the soils to surface is accounted for and therefore not precluded. However, some provinces as a matter of policy treat site closure based on subsoil generic levels to be conditional on no excavation.

A final consideration in 2000 was to factor in aesthetic, infrastructure and source issues, which were incorporated into the subsoil eco soil contact levels as an "upset" limit. These upset limits included:

- sum of all PHC fractions not to exceed 2%
- sum of F1-F3 not to exceed 1%
- F4 not to exceed 1%
- F1 not to exceed 0.1% (1000 mg/kg)

4.2.4 Subgroup Recommendations and Rationale

a. Do not include aesthetic, infrastructure and source upset limits within the subsoil eco contact pathway.

For transparency and clarity, if the CCME SQGTG wishes to incorporate these limits into the CWS, they should be addressed as an entirely separate assessment endpoint. This will give them the attention they deserve.

b. Use a level of "no value - pathway not complete" for subsoil at > 3 m depth

Based on a review of the soil invertebrate distribution and the root zone of most plants (Gordon Dinwoodie, Alberta Environment, Appendix D), ecological receptors do not occur in any significant abundance below this depth. Furthermore, this approach is consistent with the current regulatory framework in Alberta.

It should be noted that, if application the soil contact pathway is eliminated below 3 meters, either groundwater mediated transfers to surface water bodies or human health exposure pathways (potable water protection; soil vapour intrusion into buildings) would likely form the basis for remediation objectives on a case-by-case basis. This is in *lieu* of new guidance that accounts for aesthetics, infrastructure degradation, non-porous flows, or other upset limits not based on direct exposures of ecological receptors. Human health pathways for Fractions F3 and F4 are currently set at RES (Residual: 30,000 mg/kg). Vapour inhalation pathways will control Fractions F1 and F2. If individual jurisdictions allow vapour inhalation or other human health pathways to be screened out for certain land uses (e.g., Natural Areas in Alberta) and site characteristics allow groundwater protection pathways to be screened out, high concentrations could potentially be left below 3 meters.

Under this scenario, upward movement of volatile hydrocarbons has been identified as potentially presenting a stress to overlying vegetation and soil invertebrates. No evidence exists to evaluate the significance, if any, of this exposure pathway.

c. Unable to reach recommendation for "intermediate" soil (1.5 - 3m depth)

EcoSG was unable to reach a consensus on what to recommend for the intermediate soil zone, or whether a set of recommendations was indeed appropriate in the absence of any clear scientific/technical guidance. The draft CCME 2005: Protocol for the Derivation of Canadian Soil Quality Guidelines" is silent on this issue.

Several options were briefly discussed by the Sub-Group. Some options were eliminated. Those that remain are summarized below:

Option	**Rationale**
1. Use a midpoint of the factors between surface and subsoil criteria that were used in 2000 -F1 -use 2.4 -F2 -use 2.6 -F3 - use 5.2	Consistent with 2000 CWS. The factors used in 2000 were: F1 between 2.1 - 2.7 F2 between 2.0 - 3.3 F3 between 4.2 - 6.2 (3.5 represents a geometric mean of 2.4, 2.6 and 5.2)
2. Use a constant factor of 3.5 between surface and subsoil criteria	Same rationale as Option 1, except more simple.
3. Use surface soil values for Ag lands, and Option 1/2 for R/C/I	Avoids deep digging on a lot of Residential/Commercial/Industrial sites
4. Use surface soil values for Ag/Res lands, and Option 1/2 for C/I	More protective than Option 3.

EcoSG is deferring a decision on this matter to the SQGTG (See also Section 7).

5. Proposed Approach for Developing Site-Specific Remediation Objectives (Tier 2/3)

Major issues in this thematic area addressed by the EcoSG included –

- Use of site-specific toxicity tests
- Site-specific adjustments based on indicators of bioavailability

5.1 Use of laboratory toxicity tests to develop Tier 2/3 remediation objectives

As per Section 4, derivation of the Tier 1 ecological benchmarks for the soil contact exposure pathway was based primarily on data from controlled laboratory ecotoxicity tests with fresh product (e.g., crude oil, three fractions of crude oil, and fresh gasoline).

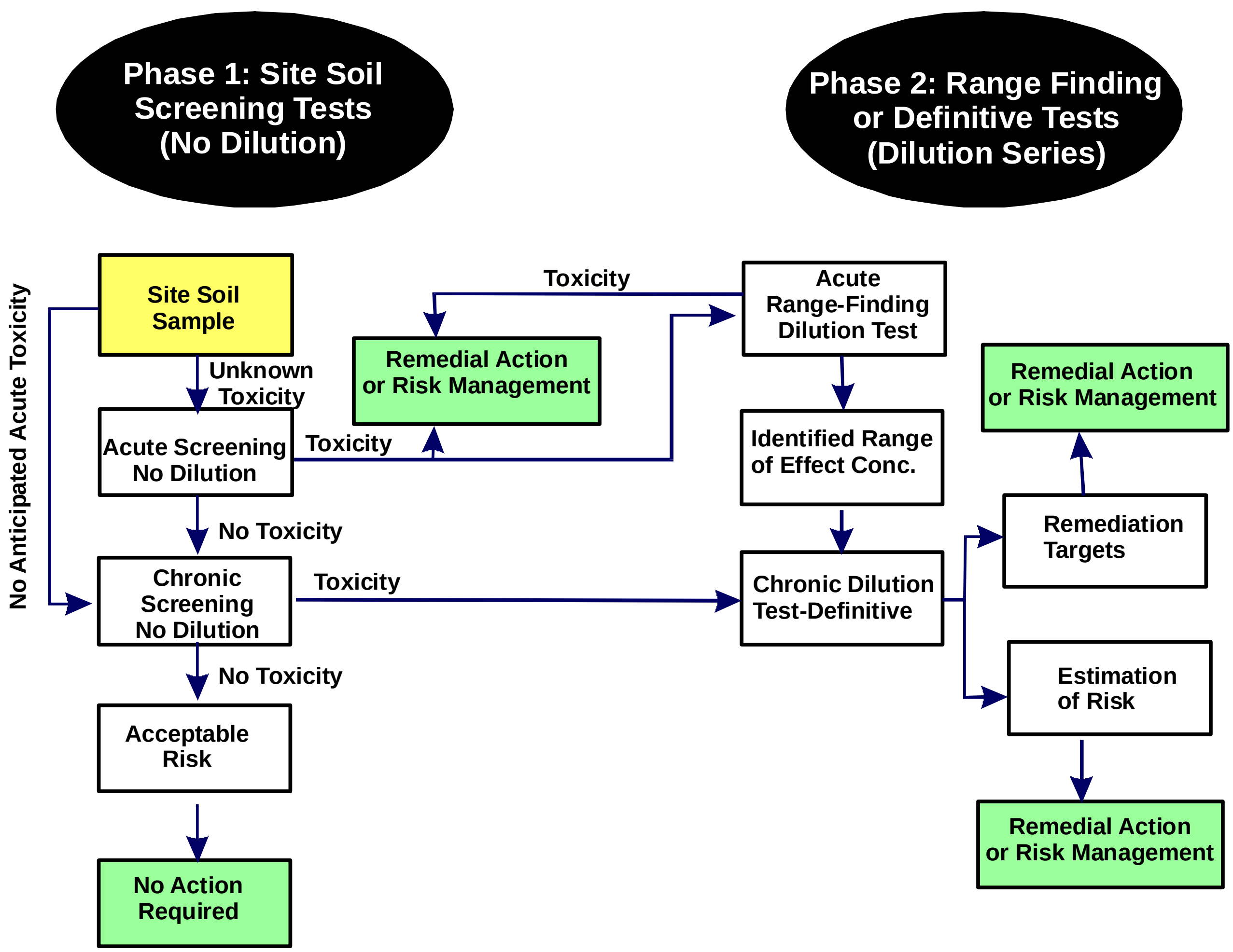
The derivation process for the fresh-product and freshly-spiked-soil based Tier 1 soil contact standards for petroleum hydrocarbons in soil explicitly involves high bioavailability of the product. When PHC-spiked soils are used in laboratory toxicity tests, bioavailability is implicitly covered to some extent. Less than 100% of the analytically measured concentration may be bioavailable in laboratory microcosms depending on soil and PHC product type used, but the ICx concentration is calculated using the entire extractable fraction. If less than 100% of the spiked PHCs was bioavailable, and if the truly bioavailable fraction was used in constructing dose-response curves, the estimated ECx would be correspondingly lower. Overall, it is important to appreciate when discussing bioavailability that the critical issue is one of relative bioavailability i.e., the proportion of bioavailable PHC in a field-collected soil as a percentage of the bioavailable fraction in the freshly-prepared laboratory toxicity tests used to establish the generic assessment and remediation benchmarks.

As with other benchmark values, the derivation process for the CW Tier 1 soil contact standards for petroleum hydrocarbons in soil explicitly assumes 100% bioavailability of the product as determined by the total soil concentration of each petroleum hydrocarbon (PHC) fraction measured in soil, using standardized procedures involving relatively aggressive solvent extraction techniques. The toxicity of fresh product to terrestrial organisms, however, is a function of exposure concentration and exposure duration. The exposure concentration, in turn, is directly related to the bioavailability of the PHC constituents comprising the contamination.

Because the bioavailability of various PHCs can be affected by both “weathering” and “aging” processes (Stantec Consulting Ltd. 2004), as well as the physico-chemical properties of soil, site-specific factors that influence the bioavailability of the PHCs on-site, need to be considered, along with the results of site-specific ecotoxicity testing, when deriving standards that are applicable at higher tiers of the assessment framework (e.g., > Tier 1 = Tier 2 or 3). At a site where there is PHC contamination in soil, the general practice is to collect soil samples and subject them to chemical analyses to determine the concentrations of the four hydrocarbon fractions using the methods stipulated by CCME. If the analytical results indicate that the PHC levels in soil exceed any one of the Tier 1 standards for that particular soil type and land use, then either remedial action or risk management is required or, alternatively, a Tier 2 or Tier 3 assessment, must be conducted. Although currently there is no process for adjusting the Tier 1 standards to accommodate site conditions and characteristics, the vision for the future is to invoke eventually the use of a “soil effects ratio” or a bioavailability factor to derive Tier 2 or 3 soil quality criteria. In the interim, a toxicity assessment of contaminated site soil, using a minimal test battery of methods and species, in conjunction with the measurement of PHC bioavailability using cyclodextrin extraction and subsequent GC analyses are recommended to support the derivation of Tier 2 or 3 soil quality criteria, as described elsewhere in this document (Section 8.2).

A framework was proposed previously for assessing the site-specific toxicity of PHC-contaminated soils to organisms directly affected by the soil eco-contact pathway (Stantec Consulting Ltd., 2005). This framework (Figure 1) provided guidance on how to initially screen site soils for toxicity, and once screened, how to obtain quantitative data that can be used to derive Tier 2 or 3 standards. Detailed guidance was also provided on how to conduct the terrestrial toxicity tests outlined in the framework, including guidance for soil and species selection, experimental design, test processing, and statistical analyses of the generated data.

Figure 1: Recommended Framework for an Ecotoxicity Assessment in Support of the Development of >Tier 1 Standards for Petroleum Hydrocarbons in Soil.



The draft guidance for conducting the terrestrial toxicity tests closely follows, for the most part, the Environment Canada biological test methods for plants, earthworms, and soil arthropods, which were in draft form at the time the framework was developed. Two of the EC test methods for assessing the toxicity of soils to plants and earthworms have been published as reports EPS 1/RM/43 and EPS 1/RM/45, respectively (EC 2004; EC 2005) and the test method for soil arthropods (collembolan) will be published as report EPS 1/RM/47 in June 2006. The Ecological Criteria Advisory Sub Group endorses the toxicity assessment approach put forth in the framework (Figure 3.1) and recommends using the EC test methods.

The framework for toxicity assessment of contaminated lands is divided into two phases (Figure 3.1). Phase 1 includes site soil screening tests using undiluted representative soil samples collected from the site. There are two purposes for the screening test: 1) to rapidly determine if there is toxicity associated with short-term (acute) exposure of the test organisms to the site soil, and 2) if there is no acute toxicity, continue the test to assess for chronic toxicity associated with prolonged exposure to the site soil. If no toxicity results from the chronic screening tests, then the risk associated with the contaminated soil is considered acceptable, and no remedial action is required because the remedial target is equal to the measured exposure concentration in the site soil. If acute toxicity is prevalent from the screening test, then a decision to either manage the risk or remediate the site might be taken. Alternatively, if acute toxicity was observed for the undiluted soils in Phase 1 testing, the site assessor might elect to implement Phase 2 and complete further testing, rather than take remedial action.

Phase 2 toxicity testing uses soil dilution methods to determine the magnitude of the soil toxicity (i.e., the range of effective concentrations or percent of site soil in clean soil that causes adverse and no effects). A range-finding test is conducted whereby the representative site soil sample is proportionally diluted with a negative control soil to generate a series of different exposure concentrations or levels of contamination (e.g., treatments). The purpose of the dilution test is to rapidly determine where the toxicity occurs and to identify the range of effective concentrations. At this point, the site manager might elect either to manage risk or take remedial action. Alternatively, further chronic definitive tests can be performed to identify the range of effect concentrations associated with prolonged exposure to sub-lethal levels of contamination. The results of these definitive chronic tests are then used, in part, to identify an acceptable remediation target, or to estimate risk associated with the level of contamination at the site.

Tests with whole soils (Phase 1) are screening tests and can be short or long in duration, depending on whether an acute response was observed or not. The aim of screening tests is to statistically discern if the site soils are “toxic” relative to the negative control soil (e.g., reference control soil). Tests with diluted soils (Phase 2) are definitive tests that generate quantitative data, and can be short or long in duration, depending on whether an acute response was seen during the multi-concentration test. The aim of the dilution tests is to determine either the percent effect (ICp) with the associated 95% confidence intervals. Two statistical approaches for calculation of an IC20, IC25 or IC50 are outlined in the Environment Canada soil toxicity methods (regression analysis and linear interpolation). Most data sets from soil toxicity testing can be analyzed by one of these methods. In the case of a dataset that is not amenable to point estimation analysis (e.g. such as bimodal data where the response is obviously not incremental) then non-continuous comparisons of treatments should be carried out. The data from the chronic definitive tests can be used, in part, to derive a Tier 2 or 3 eco-contact standard.

Universal procedures for eco-soil contact testing are described in detail in Environment Canada soil toxicity methods (EC, 2004; 2005; 2006) and Stantec Consulting (2005). A description is provided for each of the four types of tests and includes: experimental design; soil pre-test preparation; soil moisture content determination; sample calculations; soil homogenization prior to test soil preparation; hydration of soils and allocation to test units; soil physical and chemical measurements during a test (i.e., pH and conductivity); test validity criteria; and, statistical analyses of the data.

There are four species recommended as the test battery to generate toxicity data to support the derivation of Tier 2 standards for petroleum hydrocarbons in soil. These include two plant species, one earthworm species, and one soil arthropod species. The plant species include northern wheatgrass (*Elymus lanceolatus*) and alfalfa (*Medicago sativa*), a native monocotyledonous and a leguminous dicotyledonous plant species, respectively. The earthworm species is *Eisenia andrei* and the soil arthropod is a collembolan species that can be either *Folsomia candida* or *Onychiurus folsomi.* These species are recommended as test species by Environment Canada (plant test methods – EC, 2005; earthworm test methods – EC, 2004; collembolan test method –EC,2006), are known to be sensitive to petroleum hydrocarbons, and they were used for the development of the Canada-wide Tier 1 standards for petroleum hydrocarbons in soil. The test battery of species and methods represent the minimum number of species and tests for generating data for a Tier 2 assessment and, for Tier 3 assessments, the battery should include additional species that are ecologically relevant to the site being assessed.

Test designs and durations vary depending on the species and nature of the test. The test measures the effect of the contaminated site soil on seedling emergence and growth. Measurement endpoints are the same for both tests and include seedling emergence, shoot and root length, wet (optional) and dry mass. Screening and dilution tests with earthworms are used to evaluate the effect of contaminated soil on adult survival, reproduction, and growth following 56 or 63 days of exposure. If an acute response is observed early in the test, the experiment can be ended after 7, 14 or 28 days. In the chronic test, the reproduction endpoints are mean number of progeny produced per treatment and progeny mean wet (optional) and dry mass. Adult survival following 28 or 35 days is also assessed. Screening and dilution tests with collembola evaluate the effect of contaminated soil using *F. candida* or *O. folsomi* reproduction following 28 or 35 days of exposure, respectively. Adult survival at 28 or 35 days is also measured in the chronic collembolan test. Detailed guidance of the screening, multi-concentration and chronic type test methods specific for each species is provided in the Environment Canada test method (EC, 2006). It should be noted that the termination of a 56 or 63 day test in the event of acute response by 7, 14 or 28 days is not the same guidance as that for acute testing as described by EC protocol. Acute tests do have a role in making expeditious and practical management decisions, but are not suitable to define remedial or clean-up objectives.

For single-species toxicity tests with terrestrial organisms, such as those proposed in the framework, there are usually three types of soils used in a test. The first is an artificial soil that is formulated in the laboratory and for which test species performance data are available. This is a negative control soil that can be used: 1) in some instances, as a diluent for the contaminated site soil; 2) as an experimental control soil that measures the performance of the test organism under the conditions in which the test is being conducted; 3) to assess the quality or health of the test organisms; and, 4) it is used comparatively with the reference control soil to assess the degree to which the physical and chemical characteristics of the site soils influence the results of a test. The second soil is a reference soil that is collected to match the physicochemical characteristics of the contaminated site soil, but is free of contamination. The use of a reference soil in a test enables the differentiation between the effects of the physico-chemical characteristics of the site soil and the presence of contamination on toxicity to test organisms. A reference soil also can be used as an experimental control soil treatment and is the negative control soil most frequently used to dilute the site soils. The third soil is the site soil being investigated. Detailed guidance for preparing soils for ecotoxicity testing is provided in the guidance document prepared by Stantec Consulting Ltd. (2005).

Following the completion of the ecotoxicity assessment, the estimates of toxicity can be used, in part, to derive Tier 2 remedial targets for the soil contact exposure pathway. The derivation process is similar to that used for the development of the Tier 1 standards for PHCs in soil. “Ranked response approach” is the recommended method for derivation; it is described briefly, with the underlying assumptions elucidated (Appendix C).

At this point in time, the toxicity data used in the derivation of a remedial target for the site are based on a minimal data set generated by the testing recommended in herein. However, there is currently no process for integrating the toxicity test data with those resulting from a measure of bioavailability, degree of weathering or aging of the contamination, or the physico-chemical site characteristics that influence bioavailability of the petroleum hydrocarbons to terrestrial receptors (Stantec Consulting Ltd. 2004). However, the knowledge and understanding of the fate and effects of PHCs in different types of soil has grown considerably since the conception of the tiered management framework and development of the Tier 1 CWS standards for PHCs in soil. Further elucidation of the relationships between and among these factors is required in order to develop a model or formulate a process that can be used to adjust the Tier 1 CWS PHC standards to Tier 2 standards and be applicable to similar sites with similar PHC contamination.

5.1.1 Specific research recommendations:

- Develop a process for adjusting the Tier 1 PHC CWS to accommodate site conditions and/or characteristics;
- Develop a model that integrates bioavailability with toxicity, with the objective of deriving Tier 2 guidance (for example, site specific remedial objectives);
- Develop a process for site characterization that would enable application of more generic Tier 2 standards (those derived for a specific set of site conditions and or characteristics that can then be applied to other similar sites with similar contamination).

5.1.2 Expressing PHC soil concentrations when developing and applying Tier 2/3 remediation objectives

The state of science regarding site characteristics that influence the bioavailability of weathered and/or aged PHCs in soil, and methods for measuring weathered PHC bioavailability, is not sufficiently advanced to be able to confidently predict actual toxicity. There remains, therefore a need to measure ecotoxicity directly or perhaps respond conservatively to cases of hydrocarbon releases to surface soils. Until such time that predictive models are developed and validated, a number of options are proposed for identifying a concentration-based remedial objectives at sites where the Tier 1 standards are exceeded for a specific fraction or fractions.

For many jurisdictions, toxicity test results for the total mixture (TPH) of PHCs present in the soil will be sufficient for Tier >1 applications. However, in some jurisdictions, regulations or guidelines are such that it may be either required or much more convenient that the PHC results from toxicity tests be expressed as concentrations of the individual fractions than as TPH. There are, however, difficulties involved in translating toxicity test results into specific PHC fractions, as the toxicity values produced from the tests are indicative of the whole mixture existing in the soil, and may not reflect the concentration of any one fraction. It is recommended that in these situations the soils used for the bioassays be analyzed for the relevant PHC fractions and that a standardized set of procedures be used to establish fraction concentrations for the site that would not pose concerns with respect to the direct contact ecological pathway. The EcoSG feels that standardized procedures could be developed with minimal additional effort. The following provides a discourse on options for potentially viable approaches.

Path A:

Site-specific chronic or definitive testing with a battery of test species and methods can be used to assess the relative toxicity of site soils. In the event that no adverse effects related to the contamination are observed after prolonged exposure to site soils (results of chronic screening tests described in Phase 1 of the assessment framework - Figure 1), then the remedial target is equal to the concentration of the most contaminated soil sample tested from the site. We might conclude a lack of toxicity based on –

- No statistically significant difference between biological response in soils of interest and a comparable reference soil collected from the site, *and* adequate power in the experimental design to detect a difference of 20% or more;
- A statistically significant difference, but with an effect level relative to reference samples of ≤20%;
- Other?

The site-specific toxicity data in this instance is not used to develop an SSRO per se, but rather to demonstrate an overall lack of toxicity (and ecological risks based on direct soil contact), all other things being equal. Note that this would not meet the definition of a Tier 2 as opposed to Tier 3 assessment per se, since it is not possible to develop a numerical SSRO given the available data. Rather, responsible parties must develop sufficient confidence that the sampling methods and intensity, as well as toxicity test methods justify a no-action scenario for dealing with ecological direct contact type risks.

Path B:

In the event that toxicity is observed and effects concentrations determined for different endpoints and species, then the species sensitivity distributions using IC/EC25 or IC/EC50 estimates of toxicity (consistent with whatever final Tier 1 methodology is selected) can be used to identify the Threshold Effect Concentration associated with either the 50th (commercial/industrial sites) or the 25th percentile (agricultural/residential) of the sensitivity distributions. The intent of the Tier 2 investigation, therefore, would be to define a Site Specific Remediation Objective (**SSRO**) that is anticipated to be higher in value than the corresponding generic standard or guideline. To adequately define an SSRO that can then be used to establish targets for soil removal, phytoremediation, monitored natural attenuation, *et cetera*, there are three subsidiary **requirements**:

1) **Accurate contaminant concentration data for the exposure media** (soil) that is directly relevant to the toxic response(s);

2) **A sufficient number of soil samples and range of concentrations to establish statistically significant dose-response curves**, and – for each species – develop a confident IC25 and IC50 estimate. For frequently turned biopiles, there is often insufficient variability to develop dose-response relationships using toxicity testing, and a more appropriate use of toxicity tests in this case is to evaluate absolute pass-fail of the entire soil mass from a risk-based perspective;

3) **A broadly accepted decision framework for translating toxicity test data into an SSRO**. We suggest that the protocols ultimately selected for use for deriving Tier 1 soil quality guidelines for the protection of soil invertebrates and plants are also suitable for deriving SSROs. Ideally, enough data will be developed for a site to accommodate use of a Weight-of-Evidence (SSD) approach. A smaller investment in laboratory toxicity tests, in terms of numbers and type of taxa, would compel an investigator to use a Lowest LOEC or median effects approach, in both instances incorporating some degree of adjustment for uncertainty. Note that an obvious extension of this line of reasoning is that the field program and subsequent ecotoxicity testing must be amenable to the estimation of the IC25 or IC50, as appropriate.

With regard to requirement one, representative sub-samples of soils collected for ecotoxicity testing should be chemically characterized so that the strength of linear or non-linear co-variations between biological and chemical data can be assessed. A minimum suite of analytes, therefore, would include -

- Canada-Wide Standards Fractions (all unless it has already been demonstrated that one or a few of the four are contaminants of potential concern);
- Soil texture;
- Soil organic carbon;
- Moisture content and water holding capacity
- Cation exchange capacity
- Soil pH
- Electrical conductivity
- Concentrations of nutrients

In addition, if there is an interest in use of surrogate measures for guiding remediation such as TPH, TPH by field test kits, etc., then this surrogate should also be assessed. Finally, other measures of PHC concentration (β-cyclodextrin extractable F3, e.g) may be of interest.

Note that there are two major ways in estimating thresholds of effects for PHCs in site soils:

1) Use samples from the site that span a range of PHC concentrations as the basis for examining dose – response. Ideally, the samples collected at the site and submitted for laboratory analysis will bracket the IC25 or IC50 concentration, and there will be sufficient statistical power that the confidence limits around ICx estimates are relatively low.

2) Use an uncontaminated site reference soil to develop replicated serial dilutions of the most contaminated location, a large sample of which is collected for testing. The major advantage of this method is that it is more likely to lead to data that are amenable to statistical analysis and development of ICx endpoints. The major disadvantage is that dilution of a contaminated soil mass in the laboratory with an uncontaminated soil requires substantial manipulation, and may result in artefactual and unrepresentative effects relative to the field situation. In particular, each soil prepared in series using a serial dilution approach is subjected to progressively longer mixing times. One of the major concerns is loss of PHCs prior to introduction of the test organisms.

The toxicity estimates and the threshold effects concentration reflect the effects to organisms of exposure to the entire PHC mixture in soil and not the toxicity of individual fractions. However, the remedial target derived in this manner for the mixture can be manipulated to identify fraction-specific remedial targets by assuming that the toxicity to organisms is attributed to each of the fractions based on the proportional representation of the fraction in the mixture as follows:

(*Option A*)

Once toxicity data are available for each sample, the strength of co-variation between effect level and soil concentration should be examined (e.g. based on comparing the co-efficient of determination, r^2) for each of the relevant CWS fractions, as well as their sums ([F1+F2], [F2+F3], etc.). If desired, the strength of co-variation can also be compared for other measures of PHCs. Ultimately, the practitioner must be able to demonstrate that (i) the expression of soil concentration chosen for developing an SSRO is the best choice based on explanatory power for the observed biological response in a sub-set of samples; and (ii) the measure selected can be translated into an equivalent concentration based on one or more of the PHC CWS four fractions using an appropriate statistical model.

(*Option B*)

1) Using total mixture concentrations, that is, the sum of all relevant PHC fractions, establish the EC20-25 (or EC50, as appropriate) concentrations and the 25^{th} or 50^{th} percentile of the distribution of these values, as appropriate to the site.

2) Determine the soil that had the total mixture concentration closest to, but equal to or below, that of the concentration determined in step 1.

3) Use the measured PHC fraction concentrations for the soil from step 2 as the acceptable direct soil contact component. OR

4) If desired, use the ratios of the PHC fractions from step 3 to increase the fraction concentrations such that the sum of all PHC fractions does not exceed the value determined in Step 1.

(*Option C*)

1) Calculate the response curves for each relevant fraction and determine the EC25s (or EC50s as appropriate) based on the assumption that each of the fractions is responsible for all the toxicity. Calculate response curves for the total PHC mixture as well.

2) Determine the 25th or 50th percentile concentrations (as appropriate to the site) of each PHC fraction from the species sensitivity distribution, and determine the ratio of the PHC fractions at the calculated EC25s or EC25s. Also determine the 25th or 50th percentile of the EC25s or EC50s for the total mixture of PHCs.

3) Use the ratio calculated in Step 2 above, to determine the relevant fraction concentrations such that the sum of PHC fractions does not exceed the total PHC mixture concentration at the appropriate percentile of the species distribution curve.

These values can be used to give a reasonable, conservative estimate of fraction concentrations that could be considered protective at the desired level.

(*Option D*)

A proposal (Stantec Consulting Ltd., 2005) to derive Tier 2 standards on a site-specific basis using the TEC determined from laboratory results of tests using a minimal test battery was considered by the EcoSG. The TEC was derived for a particular site. The remedial target (i.e., allowable concentration in soil) for each fraction in exceedence of the Tier 1 CWS was determined by expressing the concentration as the inverse of the ratio of mass fraction equivalents of each fraction relative to the ratio of the of the Tier 1 fraction-specific eco-contact standards for PHCs in soil (see Section 7; Stantec Consulting Ltd., 2005). The EcoSG decided that this approach was not applicable to all scenarios and that the other options might be better received by regulatory agencies.

(Option E)

Due to the natural variability in soils and biological systems, and the difficulty in obtaining a truly representative control sample at many PHC-contaminated sites, the approach of looking for “no significant difference” between contaminated and control soils may not be a realistic way of assessing whether a PHC-contaminated site presents an acceptable level of risk to biota. In addition the “no significant difference” approach is inconsistent with the Tier I approach used in the PHC CWS, where the guideline concentration is set based on the 25th or 50th percentile of a distribution of effect concentrations.

The “Ranked Response Approach” (RRA, see Section 4.3.4) may offer a solution to this issue, and can be a useful tool in determining whether the responses seen in the toxicity testing of a single soil (in the absence of serial dilution data) comply with, or fail to meet the requirements of the Tier I approach used in the PHC CWS for the applicable land use.

The RRA method is a pass/fail criterion for assessing the compliance of a set of toxicity data with the intent of the CCME protocol, and may be summarized as follows (full details are available in Tindal, Visser, and Cermak, 2005; Appendix C).

- Data from the battery of toxicity tests conducted on a single contaminated soil are presented as the response relative to the control for each species/endpoint.
- Redundant data are combined or excluded.
- The data are assessed against one of the three following criteria (the choice depends on a pending SQG TG policy decision).

1. Under the CCME (2005) Approach, the concentration of hydrocarbon is deemed to meet guideline requirements for agricultural/residential land use if the 25th percentile of the ranked responses shows at least 75% of control response. Similarly, the level of adverse effects is deemed to be within the level implicit in the definition of the guideline for commercial/industrial land use if the 50th percentile of the ranked responses shows at least 75% of control response.
2. Under the Hybrid Approach (commercial and industrial land use only) the concentration of hydrocarbon is deemed to meet guideline requirements for commercial/industrial land use if the 50th percentile of the ranked responses *for the plants-only dataset* shows at least 75% of control response.
3. Under the CCME (2000) Approach, the concentration of hydrocarbon is deemed to meet guideline requirements for agricultural/residential land use if the 25th percentile of the ranked responses shows at least 50% of control response. Similarly, the level of adverse effects is deemed to be within the level implicit in the definition of the guideline for commercial/industrial land use if the 50th percentile of the ranked responses shows at least 50% of control response.

As discussed elsewhere, at some sites it may not be feasible to collect a series of soil samples with a range of hydrocarbon concentrations. Conducting serial dilution tests on a site soil brings another set of challenges, typically in collecting a representative control soil for the dilutions, and the concern that diluting the contaminated soil will affect the bioavailability of the PHC. In cases where these concerns are present, then the RRA approach may be a useful tool to assess whether a soil sample complies with the intent of the CCME protocol.

Path C:

Assume that some portion of collected soils exhibit toxicity; however, there is not a synoptic relationship between the soil concentrations (either using the CCME method, β-cyclodextrin method, or other) and magnitude of biological response. There may be one or more confounding influences, and/or the toxicity may be a result of other contaminants, but there are too few data to confidently assess this. We recommend that such complexity is beyond a simple Tier 2 assessment, and might require some form of follow-up sampling, toxicity identification evaluation, or other forms of experimentation. Such issues are beyond the scope of a Tier 2 approach.

5.2 Assessment of PHC Bioavailability from Soils for Tier 2/3 Risk Assessment: Development of a data set to correlate cyclodextrin extraction with toxicity

There is a relationship between the biological toxicity of PHC in soils, and their total concentration as defined by Soxhlet extraction (CCME); if the soils vary in properties, and the PHCs vary in condition, a significant proportion of the variation in toxicity is not explained by variation in the exposure concentration expressed as total PHC. As the toxicity threshold for regulatory purpose must include uncertainty, this large margin of unexplained variation leads to a threshold number that is considerably lower than the mean as predicted by the relationship, and lower than the threshold of field-observed biological effects. While some of this unexplained variation is undoubtedly due to true biological variation with a population of a particular species, some of it is due to the variation in bioavailability of PHC among soils and conditions. For example ageing or weathering of PHCs in soils, distribution of grain sizes, amount of organic matter, are speculated to have an influence on the expression of toxicity relative to what would be expected from measurements of total PHC in soils. Since this range of conditions is expected to be encountered among the actual soils to which the guidelines will be applied, the ability to identify the bioavailable fraction of total PHCs in soils would be useful. This concept or goal is not unique to PHCs in soils; similarly, the commitment to regulate metals in water and soils on the basis of bioavailability is well entrenched in the US EPA's Framework for Metals Risk Assessment, as

(**http://cfpub1.epa.gov/ncea/cfm/recordisplay**.cfm?deid=54465).

Reducing the unexplained variation in the mathematical relationship between toxicity and PHCs in soil, could result in a threshold that is closer to the actual mean response as predicted by the relationship, if the threshold is adjusted for uncertainty (Figure 1).

Accurately defining a relationship between toxicity and bioavailable PHC in soils would be an important component of a Tier 2 approach. Tier 2 adjustments are intended to reflect a greater depth of understanding of site conditions based on collection of easily verifiable, reproducible site information, without the expertise and allied requirements associated with the completion of a detailed, site-specific environmental risk assessment (Tier 3 approach, per CCME framework discussions). Any guidance on Tier 2 adjustments would not have the same requirements of harmonization among signatory jurisdictions to the PHC CWS, but rather would be scientific guidance that might be adopted in or otherwise have utility in individual jurisdictions at the discretion of regulatory authorities. The value of any proposed Tier 2 adjustments, therefore, will be commensurate with the strength of scientific evidence for achieving the intended site-specific adjustments, coupled with their pragmatic value for more accurately tying site assessment and remediation activities to actual ecological and/or human health risks.

5.2.1 Science Rationale

The most well-investigated non-exhaustive extraction method that is purported to mimic, or identify the bioavailable fraction of total PHC in soils is cyclodextrin. A brief summary of the literature published in the last five years follows.

Two key areas of research have preceded the focus on cyclodextrins for assessing bioavailability of PHCs in soils:

(i) Use of cyclodextrins to enhance human or veterinary bioavailability of or confer temporary stability on pharmaceuticals administered orally, dermally, by inhalation or in eye drops;

(ii) Use of cyclodextrins to enhance desorption of hydrophobic organic contaminants from soils in order to enhance *in situ* and *ex situ* contaminant degradation rates.

It is important to appreciate, therefore, that cyclodextrin amendments have more typically been used to enhance bioavailability relative to the existing availability especially to microbes or for *in situ* solvent extraction. Cyclodextrins (CDs) are cyclic oligosaccharides (*a*-1,4-linked glucose polymers, further constrained in a three dimensional cyclic form), produced in abundance by some types of microbial cultures. Hydroxyl groups in the tertiary structure are directed outward, creating a highly hydrophilic exterior and relatively hydrophobic core. The overall molecule is "amphipathic", therefore, and can form "water soluble inclusion complexes" (Shirin *et al*. 2003). In addition, CDs can be formed of six glucose units (α-CDs), seven (β-CDs), or eight (γ-CDs), and each of these core structures can take on additional alkyl or other functional groups. Random methyation of CDs apparently further enhances their water solubility (Cai *et al.,* 2005). The cavity volume increases from α-CDs, to β-CDs, and γ-CDs. It appears that cavity volume is an important determinant of uptake efficiency for lower versus higher molecular weight PAHs. Since CWS F3 mixtures are known to potentially contain large amounts of alky-PAHs, any bias in extraction efficiency across the expected size range will be very important. It is generally assumed that the core size is a primary influence on the efficiency of uptake of the inclusion complex. This is likely to be an issue for a mixture of PHC constituents spanning an effective boiling point range between nC16 and nC34. According to Cuypers *et al.* (2002) –

> "An obvious prerequisite for the formation of the inclusion complexes is that the size and shape of the target molecule (PAH) and the HPCD cavity are complementary. Although this is the case for low molecular weight PAHs, it can be calculated that high molecular weight PAHs are too large to fit in the HPCD cavity. Wang and Brusseau (1995) calculated the size of naphthalene (width–length: 0.5–0.71 nm), phenanthrene (0.58–0.78 nm), anthracene (0.5–0.92 nm), fluoranthene (0.71–0.92 nm), and pyrene (0.71–0.89 nm). The sizes indicate that naphthalene and phenanthrene fit into the HPCD cavity completely (diameter–depth: 0.75–0.78 nm), whereas anthracene, fluoranthene, and pyrene can be only partially included."

A key question that arises from a basic understanding of the mechanism of hydrophobic organic contaminant inclusion in CDs, is whether this adequately mimics conditions leading to bioavailability in microbes, soil invertebrates and plants. While uptake into the hydrophobic core may approximate some types of microbial uptake processes, it remains unclear whether this would apply in circumstances more appropriately described by aqueous-phase – lipid partitioning, DOC-lipid partitioning, POC-lipid partitioning, lipid-lipid partitioning, or through mechanisms such as pinocytosis, or geophagy (in soil invertebrates). Furthermore, generalizations about CD and bioavailability may only apply in those cases where bioavailability is controlled by slow desorption kinetics from soil, approximated by second order kinetics. There is some evidence that geophagous soil organisms or plants can independently influence desorption kinetics, and this is a subset of characteristics that may result in choice of specific plant species for phytoremediation trials.

From a methodological perspective, different researchers have used different CD complexes at different application rates, based on the particular objectives of their study, for example: Bardi *et al.* (2000) used 1% w/v β-CDs in flask slurries; Cai *et al*. (2005) used randomly methylated β-CDs (RMCD); Cuypers *et al*. (2002) used > 1:1 ratio of hydroxypropyl-β-CD (HPCD): dry sediment weight; Doick *et al*. (2005) used 1.3 g soil in 25 mL of 50 mM HPCD solution; and Pattersen *et al.* (2004) used 1 g soil in 20 mL 50 mM HPCD solution.

The results by Ramsay *et al.* (2005) suggest that realized extraction of F3 or other hydrophobic organic contaminants might be heavily influenced by the experimental/methodological conditions. According to these authors –

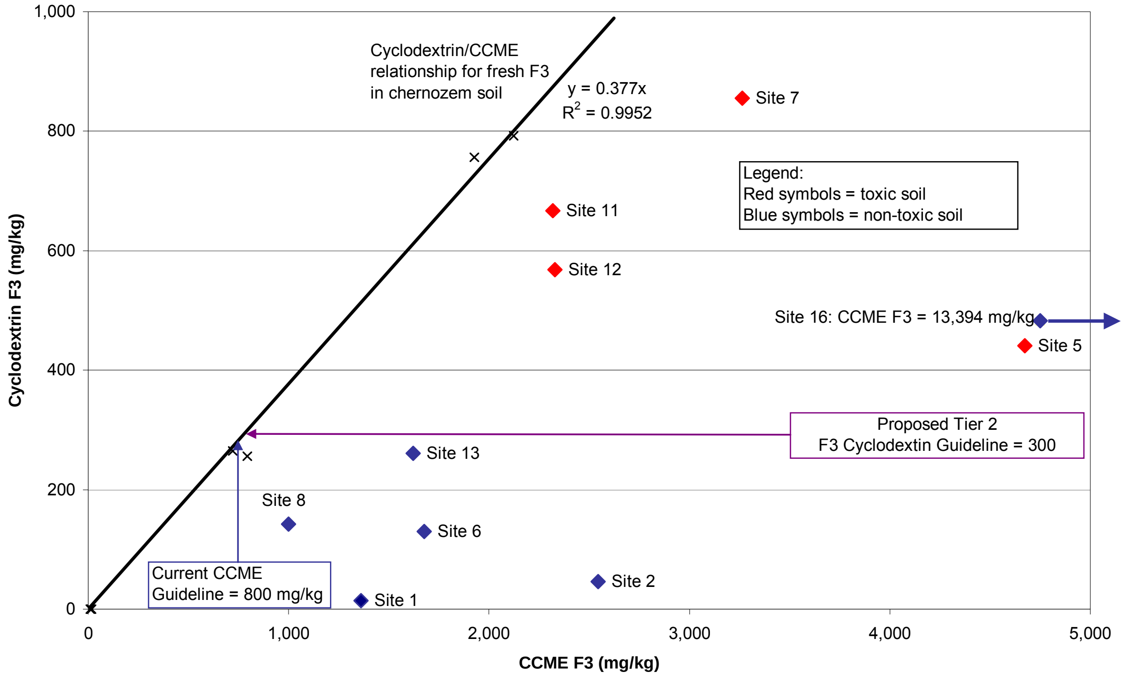
> "Amendment of a soil slurry with low concentrations of a cyclodextrin, hydroxypropyl-b-cyclodextrin (HPCD), (0.05–0.5 g L^{-1}) increased the phenanthrene mineralization rate of a microbial consortium by 25% under Fe(III)-reducing conditions. Although a higher concentration (5.0 g L^{-1}) resulted in a faster initial rate of mineralization, mineralization ceased after 25 days with maximum mineralization 17% lower than the control (no HPCD). At lower HPCD concentrations, mineralization was still taking place at day 76."

It might be expected that the concentration of "cyclodextrin F3" for a given soil sample would increase with (i) the ratio of HPCB or other CDs to soil, and (ii) contact time. Ramsay *et al.* (2005) showed that there may be interactive effects of these two that are not strictly additive. In addition, the issue of extraction times, replicability, appropriate reference materials, etc. would need to be worked out to render the technique viable in terms of routine laboratory analysis. See also the paper by Ramsay *et al.* (2005). Jozefaciak *et al*. (2001, 2003) have explored whether CD treatments of soils for *in situ* remediation purposes can alter the surface and pore properties of soil clay minerals. "The results showed that soil physical properties were greatly modified by RAMEB treatment. Analysis of water vapor adsorption isotherms revealed that RAMEB increased water adsorption and surface area in sandy soils and decreased them in clayey soils." (Jozefaciak *et al.,* 2003).

Overall, several authors have demonstrated the microbial mineralization rates are correlated with CD extraction efficiency (see Semple *et al*., 2005); however, it remains unknown whether the simple correlations can usefully lead to predictive regression relationships that (i) are applicable across multiple soil and PHC mixture types (and thus justify a single value cyclodextrin F3 concentration threshold), and (ii) adequately mimic bioavailability in the range of soil-dwelling organisms intended for protection.

Tindal (2005)[1] proposed that a "cyclodextrin guideline of 300 mg/kg developed here be used in conjunction with limited toxicity data in the closure of well-biotreated hydrocarbon soils with residual F3 greater than 800 mg/kg at Tier 2."

Figure 1. Basis for Bioavailability Index



Recommendation

The sub group recognizes that there are sufficient data to demonstrate that bioavailability has real potential to modify toxicity of organisms in a field situation, but that at this time, there are insufficient data to estimate a predictive relationship that would reliably forecast toxicity from measurements of cyclodextrin-extracted PHC in soils. To be clear, the issue is one of insufficient data to estimate the mathematical relationship, not of insufficient evidence or confidence that the relationship(s) exists. Therefore, the recommendation is that a protocol for a Tier 2 be constructed, the components of which would be limited toxicity testing, and, cyclodextrin extraction of the test soils. Through this method, the database from which a mathematical relationship between toxicity and bioavailable PHC would increase, with the goal of its establishment being that future Tier 2 requirements would be for less or no toxicity testing.

The recommended toxicity tests are as described in Section 5.1; in addition, species that are unique to the site that is being remediated, and the local situation, could be included to broaden and strengthen the data base supporting the cyclodextrin extraction as the basis for Tier 2 risk assessment. The recommended method for estimating the bioavailable fraction of total PHCs in soil is based on cyclodextrin, and the committee recognizes that an interlaboratory study would have to be implemented to develop the appropriate protocol, similar in scope to that which was carried out by CAEAL in 2002 (Malle). Preliminary cyclodextrin work has been carried out using till soil, and a well-documented procedure; however, the methodology has to be standardized, otherwise the data won't be meaningful or replicable for combining into a predictive relationship.

6. Overview of Current Knowledge Gaps

1) **Coarse vs. fine textured soils**. Soil properties influence eco-toxicity of hydrocarbon fractions, specifically, the guidelines allow more PHC for fine textured than coarse textured soils (2:1), based on the principle of irreversible sorption of PHC to fine clay particles. There is some support for the position that the guideline for the fine-textured soils is too conservative, as there are data for BTEX (for example) that indicate a ratio of 4:1 would be more appropriate. Lack of toxicity data for PHC fractions, using fine soils prevents the more specific calculation of an appropriate guideline for Tier 1. On the other hand, Cermak's admitedly very limited work on F2 suggests that there should be no difference between the fine and coarse grained soils. The committee recommends that more extensive toxicity testing be conducted on soils that are not coarse-grained, with particular attention to soil properties beyond grain size that may enhance or reduce sorption of PHC to soil particles.

2) **Cyclodextrin extraction for bioavailability**. The knowledge gap is that there are insufficient data to develop a predictive relationship between cyclodextrin-available PHC, and toxicity. The committee's recommendations to fill this gap are in Section 3.3.

3) There is considerable uncertainty around the **derivation of critical values for F1 and F2**, as their current values are lower than the lowest concentrations that were experimentally investigated. Thus, future experiments need to be designed around the concentrations of F1 and F2 that are expected to cause effect (Cermak and Tindal, 2006; Appendix E).

4) The **existing data for F1 are mostly from MOGAS exposures**, which, by the time the soil is prepared with it, is mostly F2 as the F1 is lost.

5) There is a **paucity of data which demonstrate that weathered material is not less toxic than fresh**, for F1, F2 and F4. Having said this, this issue for F1 is not high priority, as after weathering, there is expected to be little F1 left in the soil (although to what extent this is true is also a knowledge gap). However, for F4 and to a lesser extent F2, this is high priority, as for F3, weathering has been shown to reduce toxicity by 5-fold

6) The potential for **upward movement of the volatile phase of hydrocarbons** is an uncertainty that has an impact on the depth to which remediation efforts must occur. Separately, there is some uncertainty as to the maximum rooting depth of plants, and how it varies among soil-water regimes. While an approximate value can be chosen from existing data, the additional risk to plants and soil invertebrates posed by escape of volatile fractions from deep soil into the shallower rooting zone is unknown, because the potential for movement is is not known.

7) **The ecological risk for alluvial/fluvial soils posed by PHC is unquantifiable at this time**, because the species distribution, abundance and behaviour of soil invertebrates, and their role in sustainable plant communities, is not known.

8) As for most contaminants in soils, there is very poor understanding of **how effects on a particular species will influence the health of the community of species that constitute natural areas** (wildlands), either through trophic transfer of the contaminants

or though reduction in productivity or elimination of species. The latter is likely to be the more important of the two, as PHC ingested or taken up by biota would be expected to be metabolized. This is a daunting data gap to fill, but likely does not need to be uniquely filled for PHC; the effect of uneven reduction of species in a community is a subject of study in a number of disciplines, and lessons could be gleaned from those efforts.

7. SQGTG Policy Decision Review Requirements

It is anticipated that the CCME SQGTG will review the individual eco soil contact criteria developed and apply the policy decisions that would recognize which particular methods and approaches are appropriate for the guideline derivation, where such guideline alternatives existed.

It also should be noted that the guideline alternatives may have impact on the ability of responsible parties to remediate sites in a practical and cost effective manner. As such, the guideline alternatives developed are also presented to facilitate subsequent socio-economic discussions.

The EcoSG was unwilling to deliberate on issues that had policy implications in the absence of any compelling scientific/technical basis for evaluating various options; however, we recognize the need for the SQGTG to review and render decisions regarding the following guideline development considerations:

1. The premise that it is not necessary to intentionally protect soil invertebrate viability in soils at commercial and industrial sites, in those cases where soil invertebrates are likely to be more sensitive in plants. In keeping with the original derivation of the PHC CWS, it has been proposed that there should be maintained an ability of soils on commercial and industrial sites to grow various types of plants for aesthetic purposes; however, the husbandry practices involve substantial human intervention, and successful plant growth is not dependent on ecological roles played by soil invertebrates. In recognition of this, there may be merits to the use of the CCME 2000 derivation methodology, including plant-only data set at 25% and/or 50% effects level for the consideration of commercial/industrial land use, EC-Low criteria derivations (Sections 4.1, 4.2, 4,3);

2. Hybrid or modified-CCME data sets, such as using combined plant data at 25% TEC level, and invertebrate data at 50% TEC level, used in the species sensitivity distributions to derive guidelines (Section 4.1, 4.2, 4.3);

3. Proposed adjustments to F3 guideline values using field validation studies, which by their nature may involve some degree of weathering/aging. The SQGTG is asked to evaluate the pros and cons of combining weathered and fresh fraction F3 data set used to derive the F3 guidelines (Section 4.3);

4. Removal from the current PHC CWS of eco soil contact numbers for subsurface soils (> 3 m), for which there is no viable exposure pathway, in concert with a more formalized approach for addressing other concerns about residual PHCs in subsurface soils.

5. Intermediate soil zone options (Section 4.4).

8. Summary Recommendations

As discussed in Section 1, the Ecological Criteria Advisory Sub Group (EcoSG) examined the following major issues:

- Toxicity of weathered hydrocarbons relative to Tier 1; appropriateness of F3 ecological soil guidelines, based especially on potential effects of weathering on toxicity (SQGTG *Issue 7*);
- Review of the use of EC_{50} in establishing the soil eco-toxicity criteria (*Issue* 9);
- Correction for F3 analytical recovery (*Issue 11*);
- Stringency of the F3 standards (*Issue 15*);
- Development of bioavailability index (*Issue 8*);
- Development of Tier 2 guidance for eco contact (*Issue 14*).

It was recognized that several of these were inter-related. In particular, these issues were re-categorized by the EcoSG to facilitate our deliberations. The EcoSG also expanded our deliberations regarding the ecological criteria to include:

- the F1, F2 and F4 generic numerical standards in light of new information arising since 2000;
- surface versus sub-surface soil concentrations; and
- protective thresholds for fine-textured versus coarse-textured soils.

8.1 Critical evaluation of the existing generic numerical standards

8.1.1 Appropriateness of the existing PHC CWS for ecological direct contact in light of updates to CCME derivation protocols since 2000, including use of EC50 (CCME, 2000) versus EC25 (CCME, 2005) endpoints for constructing apparent species sensitivity distributions (Issue 9).

The sub group concludes that updates to the CCME protocols (CCME, 2005 draft) would have had minor influence on the outcome of the derivation of the PHC CWS in 1999 with two key exceptions.

- The PHC generic numerical standards for ecological direct soil contact exposures were derived for commercial and industrial land uses using only the ecotoxicity data for plants, while for agricultural and residential/urban parkland land uses, the standards are based on the apparent species sensitivity of both plants and soil invertebrates. It was earlier observed that soil invertebrates tend to be more sensitive to PHCs than the plant species for which toxicity data are available. The focus entirely on plant protection in the absence of soil invertebrate protection for commercial and industrial lands was based on the premise that, while a functioning soil invertebrate community is assumed to be important for plant growth in an agronomic, residential garden, or parkland-type setting, commercial and industrial landscapes tended to be intensively managed, and the development of plantings and landscapes for aesthetic purposes relied more on active management, including fertilization and soil amendments, than processes undertaken by soil invertebrates.

We find no compelling scientific/technical argument that would further the discussion on this point relative to the original decision. We defer the decision of whether to use plant-only data, or combined plant and invertebrate data each based on 20(25%) effects levels endpoints, or a hybrid combination of plant data based on 20(25%) effects level and invertebrate based on 50% effects level, for commercial/industrial land use to the SQGTG as an issue of policy.

- The original derivation of the PHC CWS marked the first occasion that a Canadian soil quality guideline was derived using a more formalized species sensitivity distribution (SSD) approach – a departure from the derivation protocols outlined in CCME (1996). To facilitate a more standardized comparison of sensitivity across species, en route to establishing an overall apparent species sensitivity distribution, those involved in the original derivation selected EC_{50} and LC_{50} endpoints as estimates that are statistically robust; i.e., are less prone to variation based on different non-linear models used in developing statistical dose-response curves, and exhibit a lower variance:mean ratio than effects estimates at lower exposure concentrations. The CCME (2005-draft protocol) prescribes selection of data for input into an SSD approach based on IC_{25} endpoints (EC_{25}, LC_{25}, etc.). This is apparently based on concern that a 50% effect level is not protective.

  The EcoSG notes that the degree of protection afforded by soil quality guidelines and similar effects thresholds using SSDs is related at least as much to the chosen percentile of the SSD (5^{th} %ile, 25^{th} %ile, 50^{th} %ile, etc.) as it is to the standardized effect size for individual taxa. While the SQGTG deliberations have focussed on effects size, further discussion is required on how various combinations of percentile thresholds from SSDs and effects sizes for the data used to construct them may translate into ecological effects at the release sites of interest (for example, based on changes in primary productivity or C/N/P cycling in agricultural settings; or changes in primary productivity, secondary productivity, biodiversity, habitat value, and C/N/P cycling in some other settings).

  From a scientific/technical perspective, we offer only one point. Use of a lower effects level ($\leq$ 25%) may result in rejection of some ecotoxicity data, since the estimate may be bounded by a very high degree of uncertainty, and may in some cases be an unbounded estimate. Should we be using the lower 95% confidence limit around an IC25 estimate? To the extent that CCME (2005-draft) guidance influences researchers who develop data that are used in the derivation of soil quality guidelines, the change might result in more complex study designs, with more exposure concentrations. From a policy perspective, the SQGTG should consider the relative challenges in understanding how a 25^{th} %ile of either an EC_{50} or an EC_{25} distribution translates in terms of lost ecological productivity, biodiversity, or some other valued property of soils, as well as any socioeconomic differences related to this shift.

  Having made the above points, we defer the decision of whether to use an IC50 or IC25 basis for eco-contact guideline development to the SQGTG.

8.1.2 Correction for F3 analytical recovery: Estimated exposure concentration in soil ecotoxicity test units – nominal versus measured concentrations (Issue 11)

There exists considerable uncertainty regarding the magnitude of adjustments made during the original studies to account for losses of F3 hydrocarbons and potentially F2 between the time of spiking into test soils and the period in which the test organisms would be exposed. This is important, since the originally developed IC_{50} data were based on regressing biological response data on the nominal concentration, the IC_p were then used in construction of an apparent species sensitivity distribution, and the resulting effects threshold adjusted after the fact to account for predicted differences between the nominal (spiked) and analytically measured exposure concentrations. The EcoSG investigated the issue extensively, including discussions with the research scientists who undertook the original PHC analytical work. While it is apparent that the reported losses from spiked soils of F3 were much higher than expected based on more recent experience, the EcoSG could not find a reasonable method for proposing a potentially more accurate quantitative estimate of loss, and of estimated exposure concentrations relative to nominal concentrations. At best, we conclude that the exposure concentration for F3 for the original toxicity tests was somewhere in the range between 31% (as originally reported) and 100% (as suggested by more recent experimental work, Appendix G). In lieu of a viable approach for re-evaluating the original data, the EcoSG recommended a validation approach for the existing numerical guidelines, where possible by referral to plant and soil invertebrate responses in field trials.

8.1.3 Stringency of F3 generic standards relative to observed effects at hydrocarbon release sites (Issue 15)

We have examined all original and new (since 2000) data on plant or soil invertebrate responses to CWS F3. It was decided by the EcoSG that a major test of the validity of the existing generic numerical guidelines for F3 was the field study lead by Dr. Visser, incorporating experimentally oiled field plots on both a fine-textured and coarse-textured soil. Based on all data produced from 2000-2005, it has become evident that limited effects on field communities of soil invertebrates may occur in coarse soil at or below an F3 value of 400 mg/kg, which is the CWS standard for agricultural/residential land. Conversely, the Visser field study suggested that the existing CWS F3 numerical standard for fine textured soils may be overly conservative.

Overall, we propose that one option is as follows:

		Current Standards	New Value
Ag/Res	Coarse	400 mg/kg	300 mg/kg
	Fine	800 mg/kg	1,300 mg/kg
C/I	Coarse	1,700 mg/kg	no change
	Fine	2,500 mg/kg	no change

This proposed option is based on *validation* as opposed to an updated *derivation.* Some of the information used to decide whether the existing values are adequately protective was based on laboratory ecotoxicity studies completed since 2000, and the data subsequently manipulated in accordance with CCME (2005-draft) protocols. Other sources of validation have been based on a "*ranked response approach*", which is different than a SSD approach.

The primary basis for recommending an increase in the Ag/Res F3 value in coarse soils from the current value of 800 mg/kg to 1,300 mg/kg is the observation of no difference in the soil invertebrate community between experimentally oiled fine soils and reference soils after three years (Visser, 2005), or of any other apparent effect. The evaluative approach, therefore, is the same as was used as our basis for a recommendation to decrease the F3 value in coarse textured soil.

An important consideration for the SQGTG in rendering a decision is that the guiding study behind this option for revision reflects an experimental plot in which the introduced oil had aged and weathered to some degree over three years. The results, therefore, might not apply to a fresh as opposed to weathered/aged hydrocarbon release. Field trials provide an excellent basis for validation of soil quality guidelines that have been derived primarily using laboratory ecotoxicity studies in one or a few soil types; however, such studies by their very nature include some degree of weathering and/or aging of organic contaminants of limited persistence, which progresses from the date of contaminant application, through the trial duration. Especially in the case of CWS F1 and F2, it is not practically possible to simulate exposure in the field to an entirely fresh PHC source, unless biological impacts within the first few hours or days is an investigative focus. For CWS F3, shorter-term field responses tend to represent the effects of a fresh product, while longer term responses (for example, six months or more) likely include some influence of weathering.

The Tier 1 PHC CWS are intended to be protective at sites of both fresh and weathered PHC releases. A second option for the SQGTG, therefore, is to leave the F3 concentration for fine soils in an Ag/Res setting unchanged from the originally derived numbers (i.e., based on laboratory toxicity data, but not modified based on the outcomes of one or more field studies). A counter to this argument, however, is that the PHC CWS are generally applied in addition to spill response measures. Site remediation would rarely occur for F3 PHC releases that are much younger than the PHC mixture in soils experimentally oiled by Visser. If the Tier I F3 value is not entirely protective of releases of fresh PHCs, by virtue of consideration of field validation results, then at most the expected effect would be temporally limited, and very likely self-correcting in the vast majority of circumstances. It bears remembering that Tier 1 soil guidelines represent targets for remediation (i.e., numbers to work down to when assessing and managing already contaminated soils) as opposed to threshold levels that should not be exceeded by virtue of intentional PHC additions to soil systems (e.g. through organic materials disposal).

EcoSG submits that this is as much a policy issue as a scientific/technical issue: Validation of a generic guideline intended to address both fresh and weathered/aged releases using a three year old release, and remediation of fine soils sites to an F3 concentration of ~ 1,300 mg/kg may mean that the residual soils with CWS F3 hydrocarbons in a range of approximately 800 mg/kg to 1,300 mg/kg could lead to some impacts on soil dependent biota. To the extent that results of Visser's (2005) study are generalizable, however, we expect the impact to be of limited temporary duration i.e. until the release has sufficiently weathered/aged.

8.1.4 Appropriateness of F1 generic standards in light of new knowledge (new issue)

We recommend that F1 numeric standards be modified based on a re-calculation to address especially the F1 versus mogas data issue, as well as consistency with CCME (2005-draft). Most of the available laboratory toxicity data are for mogas, rather than a more deliberately fractioned or manufactured mixture that contains only F1 PHCs. Mogas contains both very light PHCs (e.g. pentane) and some quantity of F2 PHCs. Especially the F2 portion of mogas is expected to result in departures from F1 in especially toxicity from chronic as opposed to acute exposures. For some species, both F1 and mogas ecotoxicity data exist that meet minimum data quality requirements. Where data are available, we propose that these should take precedent over mogas data. This will render the guideline values consistent with the latest CCME (2005-draft) protocols, and utilizes data for which estimates of nominal versus exposure concentrations are available, and for which there is greater certainty relative to the originally used mogas data.

If this recommendation is accepted, the implications for the numerical values are as follows:

Table 1a: Guideline Values for F1 Surface Soils - Combined F1/Mogas Data

	Fine Soil[3]		**Coarse Soil**	
	Ag/Res (mg/kg)	**Com/Ind** (mg/kg)	**Ag/Res** (mg/kg)	**Com/Ind** (mg/kg)
Existing Guideline: CCME (2000)[1]	**260**	**660**	**130**	**330**
Guidelines Based on CCME (2005) Methodology[2]	**210**	**320**	**210**	**320**

ag/res = agricultural/residential
com/ind = commercial/industrial

1. CCME 2000 methodology uses a distribution of IC/LC50 data, and uses the 25th percentile of the combined plants and invertebrate dataset for ag/res, and the 50th percentile of the plants-only dataset for com/ind.
2. CCME 2005 methodology uses a distribution of IC/LC25 (or 20) data, and uses the 25th percentile of the combined plants and invertebrate dataset for ag/res, and the 50th percentile of the combined plants and invertebrate dataset for com/ind. Preference given to Fraction F1 data; if no data for Fraction 1 available, then mogas data used.
3. No significant difference was observed between the toxicity of mogas in coarse- and fine-grained soils. Therefore, it was recommended by Cermak and Tindal (2006, Appendix E) that the same criteria be used for both coarse- and fine-textured soils.

The committee also considered several alternates to the CCME 2005 recommended approach; adoption of any of these is a policy decision on the part of the SQGTG. Their values are presented in Table 1b. The basis for derivation, and science justification are as follows. For the Hybrid Methodology, the rationale is that while a functioning soil invertebrate community is assumed to be important for plant growth in an agronomic, residential garden, or parkland-type setting, commercial and industrial landscapes tended to be intensively managed, and the development of plantings and landscapes for aesthetic purposes relied more on active management, including fertilization and soil amendments, than processes undertaken by soil invertebrates.

Table 1b: Policy-based Guideline Values for F1 Surface Soils - Combined F1/Mogas Data

	Fine Soil[1]		Coarse Soil	
	Ag/Res	**Com/Ind**	**Ag/Res**	**Com/Ind**
	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)
Guidelines Based on Hybrid Methodology [2]	**260**	**380**	**260**	**380**
Guidelines Based on modified CCME (2000) Methodology-Revisited [3]	**410**	**620**	**410**	**620**
Guidelines Based on CCME (2000) Methodology - Revisited [4]	**410**	**670**	**410**	**670**

1. No significant difference was observed between the toxicity of mogas in coarse- and fine-grained soils. Therefore, it was recommended by Cermak and Tindal (2006, Appendix E) that the same criteria be used for both coarse- and fine-textured soils.
2. Hybrid methodology uses a distribution of IC/EC/LC25 data for plants and IC/EC/LC50 for invertebrates, combined into one data set. It then uses the 25th percentile of the combined dataset for ag/res, and the 50th percentile of the combined data set for com/ind.

Preference given to fraction F1 data; if no data for Fraction F1 available, then mogas data used instead.

3. Modified CCME 2000-Revisited methodology uses a distribution of IC/EC/LC50 data, and uses the 25th percentile of the combined IC/LC/EC50 plants and invertebrate endpoints dataset for ag/res, and the 50th percentile of the combined IC/EC/LC50 plants and invertebrate endpoints dataset for com/ind. Preference given to Fraction F1 data; if no data for Fraction 1 available, then mogas data used.
4. CCME 2000 methodology-revisited uses a distribution of IC/EC//LC50 data, and uses the 25th percentile of the combined plants and invertebrate dataset for ag/res, and the 50th percentile of the plants-only data set for com/ind.

8.1.5 Appropriateness of F2 generic standards in light of new knowledge (new issue)

It is recommended that F2 guidelines be modified as follows (this will render the guideline values consistent with the latest CCME (2005-draft) protocols, and incorporates data developed since 2000):

Table 2a: Re-derived Guideline Values for F2 Surface Soils

	Fine Soil		Coarse Soil	
	Ag/Res	**Com/Ind**	**Ag/Res**	**Com/Ind**
	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)
Existing Guideline: CCME (2000)[1]	**900**	**1500**	**450**	**760**
Guidelines Based on CCME (2005) Methodology [2]	**150**	**260**	**nd**	**nd**

nd = not determined. Insufficient data for derivation of coarse-grained soil; na = not applicable; ag/res = agricultural/residential; com/ind = commercial/industrial

1. CCME 2000 methodology uses a distribution of IC/EC//LC50 data, and uses the 25th percentile of the combined plants and invertebrate dataset for ag/res, and the 50th percentile of the plants-only data set for com/ind.
2. CCME 2005 methodology uses a distribution of IC/EC/LC25 (or 20) data, and uses the 25th percentile of the combined plants and invertebrate dataset for ag/res, and the 50th percentile of the combined plants and invertebrate dataset for com/ind.

In addition (as for F1), the SQGTG is asked to deliberate on the further consideration of use of plant-only (IC20) data and also hybrid approach data (i.e., plant LC/IC20, and invertebrate LC/EC50 data) for numerical standards for commercial and industrial land uses. This option would increase F2 numbers relative to provided above; i.e. 230 mg/kg for plant-only and 280 mg/kg for hybrid approach, and for both fine and coarse-textured soils (Table 2b). The technical rationale for acceptance of this option remains the same as for the original derivation.

Table 2b: Policy-based Guideline Values for F2 Surface Soils

	Fine Soil		**Coarse Soil**	
	Ag/Res	**Com/Ind**	**Ag/Res**	**Com/Ind**
	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)
Guidelines Based on Hybrid Methodology [1]	**180**	**320**	**nd**	**nd**
Commercial/Industrial Guideline Based on 50th percentile of 25%Plant-only Effects Data [2]	**na**	**300**	**na**	**nd**
Guidelines Based on CCME (2000) Methodology-Revisited [3]	**390**	**980**	**nd**	**nd**

1. Hybrid methodology uses a distribution of IC/EC/LC25 data for plants and IC/EC/LC50 for invertebrates, combined into one data set. It then uses the 25th percentile of the combined dataset for ag/res, and the 50th percentile of the combined data set for com/ind.
2. Used available LC/IC20(25) plant effects, acute and chronic data. See Figure 3 in Cermak and Tindal, 2006 (Appendix E)
3. CCME 2000-Revisited methodology uses a distribution of IC/LC/EC50) data, and uses the 25th percentile of the combined plants and invertebrate dataset for ag/res, and the 50th percentile of the plant-only data set for com/ind..

There were insufficient data for the derivation of criteria for coarse-textured soils. There was no consistent difference between the ecotoxicity of Fraction 2 in fine- as compared to coarse-textured soils based on the limited available data; in fact, Fraction 2 appeared to be slightly more toxic in fine-textured soils (lower LC/IC50 values). Thus, the data do not support the hypothesis that petroleum hydrocarbons in fraction F2 should have a lower toxicity in fine-grained soil, and thus our recommendation is that the new F2 guideline for coarse soil should be the same as the new F2 guideline for fine soil.

8.1.6 Appropriateness of F4 generic standards in light of new knowledge (new issue)

The numerical values for CWS F4 were initially based on non-fractionated whole federated crude oil; however, new soil invertebrate and plant laboratory toxicity data have been developed since the original derivation. Soil quality guidelines for F4 based on these new data were calculated in this report, and were not substantially different form the existing guidelines. Accordingly, the EcoSG recommends that the existing guidelines for F4 be retained without change.

8.1.7 Generic numerical guidance for surface versus sub-surface soils (new issue)

It is recommended that subsurface guideline values (i.e. for soils at depths greater than 3 m) are not relevant based on direct soil contact for ecological receptors, since there is no viable exposure pathway. EcoSG does not wish to discount the possible importance of managing deeper subsurface petroleum hydrocarbon masses for any of a variety of other reasons; however, the mis-communication of such management approaches as being related to the protection of soil invertebrates and plants creates confusion among the user audience and may be counter-productive to a more vigorous discussion of the other management drivers.

Subsurface guidelines might be relevant for soil between 1.5 and 3 m. This, in turn, assumes that (i) soils in this depth zone are within the rooting zone for some plant species, and (ii) there is a reasonably strong scientific basis for expectations of a higher PHC toxicity threshold above versus below 1.5 m (or any other depth within the maximum expected rooting zone depth).

The current CWS includes aesthetic, infrastructure and source upset limits within the subsoil eco contact pathway. EcoSG recommends that these factors be removed from the eco contact pathway and considered separately.

The CCME (2005-draft) protocol is silent on methodology for calculating subsurface eco-contact guideline values. EcoSG was unable to identify a suitable technical basis, and was not universally convinced that there is a strong scientific basis at the current time for differenting between an upper and lower rooting zone, when considering tolerable limits for PHCs. For example, rooting success in deeper zones may be fundamentally important to drought tolerance in some plant species. Nonetheless, a few options were proposed by individual EcoSG participants, and these are faithfully transmitted to the SQGTG:

Option	**Rationale**
1. Use a midpoint of the factors between surface and subsoil criteria that were used in 2000 • F1 -use 2.4 • F2 -use 2.6 • F3 - use 5.2	Consistent with 2000 CWS. The factors used in 2000 were: F1 between 2.1 - 2.7 F2 between 2.0 - 3.3 F3 between 4.2 - 6.2
2. Use a constant factor of 3.5 between surface and subsoil criteria	Same rationale as Option 1, except simpler.
3. Use surface soil values for Ag lands, and Option 1/2 for R/C/I	Avoids deep digging on a lot of Residential/Commercial/Industrial sites
4. Use surface soil values for Ag/Res lands, and Option 1/2 for C/I	More protective than Option 3.

8.1.8 Generic numerical guidance for fine-textured versus coarse-textured soils (new issue)

Implicit in our recommendations for CWS F1 and F2 (above) is that the limited evidence does not currently support different numerical standards for coarse-textured versus fine-textured soils. It remains possible, however, that future studies will better evaluate the effects of textural variation, along with other potentially important soil properties, such as organic carbon content, moisture content, *et cetera*.

Conversely, EcoSG tentatively supports continued use of an adjustment factor to establish different CWS F3 and CWS F4 numerical guidelines for fine-textured versus coarse-textured soils. In contrast to the situation for F1 and F2, we are not aware of any laboratory toxicity data that leads us to doubt this approach. Perhaps more importantly, it is particularly clear from one field study that soil textural differences do lead to profound differences in soil ecotoxicity thresholds for the heavier CWS PHC fractions.

8.2 Development of guidance toward the use of site-specific assessment and remediation approaches

Toxicity of weathered hydrocarbons relative to Tier 1: appropriateness of F3 ecological soil guidelines, based especially on potential effects of weathering on toxicity (*Issue 7*), in particular, use of site-specific toxicity tests for sites with potentially aged and weathered hydrocarbon releases. Please see our recommendations under the next two headings.

8.2.1 Development of a bioavailability index

There is strong support for an expanded capacity relative to the current state to account for site-specific differences in (i) soil characteristics, (ii) composition of the actual PHC mixture released, and (iii) degree of aging in soil of the release. The EcoSG concur that quantifying the cyclodextrin-extractable fraction of PHCs is among the most promising tools at the present time for assessing the bioavailable fraction. There remains uncertainty about the extent to which cyclodextrins in soil systems adequately mimic the range of biological uptake processes for PHCs, and the effects of experimental conditions on the apparent answer; however, the early adoption of this technique as an addendum to other lines of evidence initially will very much help address the outstanding scientific questions.

8.2.2 Development of Tier 2 guidance for eco-contact

It is recommended that standardized guidance be developed on use of laboratory ecotoxicity tests for more site-specific approaches to the assessment and remediation of PHC contaminated soils. The guidance would be intended as a resource available to individual jurisdictions within Canada and to contaminated site/risk assessment professionals.

Particulars of the guidance will undoubtedly be developed in the near future, and there may be several options for the actual implementation of use of toxicity tests when deriving site-specific remediation objectives and/or risk management approaches.

Use of an appropriately large battery of test organisms would allow for the calculation of site-specific remediation objectives based on a Weight-of-Evidence calculation that is consistent with CCME (2005-draft) guidance for the development of soil quality guidelines for soil invertebrate and plant protection. More limited site-specific data may facilitate a "Lowest LOEC" or "Median Effects" type of approach; however, these will require the use of reasonably large uncertainty factors, and would still be subject to minimum data requirements for validity.

When engaged in site-specific work, responsible parties and practitioners are strongly encouraged by the EcoSG to collect synoptic data on all of (i) soil chemistry (including analysis using the CWS approved method), (ii) biological response data (both field observations and laboratory ecotoxicity test results) and (iii) estimates of PHC bioavailability.

9. References Cited

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10. Appendices

Appendix A: Ecological Advisory Sub Group Members

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Appendix B: Soil Quality Guidelines Task Group, Ecological Criteria Advisory Sub Group - Terms of Reference

MANDATE

The mandate of the Ecological Criteria Advisory Sub Group is to develop recommendations and advise the CCME Soil Quality Guidelines Task Group with respect to ecological soil contact values for Petroleum Hydrocarbon contaminants in soil. Specific activities to be undertaken by the Sub Group include:

- Review the relevant information submitted to CCME with respect to ecotoxicity of petroleum hydrocarbons in soil. This includes information on appropriate effects concentration to apply in the Canada-Wide Standard and information supporting revisions based on toxicity and bioavailability of weathered hydrocarbons and potential for use of these factors under a tier 2 protocol.

- Obtain and review any information that may be directly relevant to submissions that were made to CCME.

- Develop terms of reference and direct any research/review activities that may be undertaken to complete the task.

- Examine relevant policy and protocol decisions that have been developed since the original CCME Canada-Wide Standard for Petroleum Hydrocarbons in Soil.

- Determine if there are relevant and significant technical or policy changes since the development of the CCME Soil Quality Guidelines for Petroleum Hydrocarbons in Soil that may result in substantial changes to the current toxicity guidelines.

- In keeping with the appropriate CCME protocol framework, develop updated recommendations and rationale for ecological toxicity reference values and guidance documents.

- Prepare a final report including the recommendations and rationale for any necessary updates to the CCME PHC CWS standard for the Soil Quality Task Group by November 1, 2005.

The Sub Group will report to the CCME Soil Quality Guidelines Task Group (SQGTG) on a regular and timely basis about its activities and work progress. The SQGTG will approve all activities proposed and completed by the Sub Group.

REPRESENTATION

The Sub Group membership will be limited to a maximum of eight to ten members with at least one of these members from the SQGTG. Other Sub Group members will include technical experts in the field as well as interested SQGTG members.

METHOD OF OPERATION

The Sub Group will operate on the basis of consensus, as established under CCME, and directed by the SQGTG:

The Sub Group may:

1. Establish working relationships with other Sub Groups of the SQGTG, or with other agencies (government or non-government) in areas of mutual interest.

2. Identify projects along with funding sources within the area of its mandate. Funding for Sub Group projects may come from CCME or other agencies, and will be part of the annual SQGTG budget.

The Soil Quality Guidelines Task Group will recommend and appoint a chair for the task group. The chair will call meetings and teleconferences, and will establish the agenda. The Soil Quality Guidelines Task Group will recommend and appoint a consultant to the task group that will be responsible for compiling a final recommendations and rationale document as directed by the task group.

SUB GROUP SUPPORT

The CCME Secretariat will provide policy support to the Sub Group.

TIMEFRAME

The SQGTG will review the mandate of the Sub Group from time to time. The Sub Group will sunset once the Sub Group’s list of activities has been completed.

Appendix C: Tindal/Visser/Cermak (2005) Report

(in accompanying electronic file)

Appendix D: Rooting Depth Memo

Prepared for Ecological Criteria Advisory Subgroup

Gordon Dinwoodie
Alberta Environment

Issue Overview

Current CCME soil quality guidelines include direct soil contact exposure pathways for ecological receptors in subsoil (>1.5 m in depth). For the purposes of guideline derivation, the CCME *Protocol for the Development of Canadian Soil Quality Guidelines for the Protection of Environmental and Human Health* defines a minimum acceptable dataset for the direct contact eco-pathway based on plant and soil invertebrate toxicity. The Ecological Criteria Advisory Subgroup has agreed that at some depth ecological receptors do not occur and that this depth should be established on the basis of a review of soil invertebrate and plant rooting depth and activity.

Soil Invertebrates

Most soil fauna inhabit the top 20 to 50 mm of soil (Newman, 1988). Larger organisms, such as termites and earthworms, can penetrate much deeper. Of the soil fauna found in Canada, anecic earthworms likely explore soil to a greater depth than other invertebrates. *Lumricus terrestris* burrows can reach 1.5 to 2.4 m in depth (Edwards and Bohlen, 1996).

Plants

Maximum rooting depth varies with species (Table 1). Most agricultural crops reach a maximum rooting depth of approximately 1.5 metres. Exceptions are corn, which can reach over 2 metres, and sunflower, which can reach 3 metres. A number of horticultural crops will root to 3 metres in depth. Some crops, such as beets and carrots would commonly be harvested before reaching maturity and maximum root depth. However, perennial crops like asparagus and rhubarb would have ample opportunity to reach full rooting depth. Some forages, such as alfalfa and red clover can reach depths of 3 metres or more. Data is scarce for forest species, but available data indicates that trees will root to over 1 metre. Some native prairie species, predominantly forbs, will root to 3 meters and in the case of wild rose, significantly deeper.

Roots are not distributed uniformly with depth (Tables 2 – 4). Typically, surficial soil horizons (LFH, A horizon) contain the largest proportion of roots and the root mass at the depth of maximum root penetration can be quite small. Root activity is correlated to root distribution under optimal moisture and nutrient availability. Hydrologists sometimes use the following guideline for estimating the contribution of roots to water use when the soil profile is uniformly moist: 40% of water is taken up by the first quarter of the root zone, 30% by the second quarter, 20% by the third quarter and 10% by the fourth quarter (Wallach, 1990). When soil resources are not uniformly distributed, as is usually the case, root distribution can be a poor predictor of root activity, as illustrated by Table 5. During the initial sampling period (April 9 to May 13), surficial soil water was sufficient to meet crop needs and the roots below 30 cm did not take up water. All roots contributed to water uptake, in proportion to their mass distribution, during the next sampling event. Under drought conditions in the third sampling event, the deepest roots (3% of total biomass) contributed 19% of the crops water needs. Thus deep roots can play an important role in plan productivity, despite their minor contribution to total root mass. A maximum depth for ecological exposure must consider root activity under variable environmental conditions.

Conclusions and Implications

A 3-metre cut-off would accommodate soil invertebrate distribution and the root zone of most plants in Tables 1 to 4. Uncertainties include the small data set for forests; no data is presented for eastern hardwood or rain forests. There are a few deep-rooted crops and native prairie species that approach or exceed 3 metres. A 3-metre root zone allows roots to explore a large volume of soil. Restricting the root zone to 3 metres would not likely cause a significant reduction in yield, unless moisture was quite limiting (Table 5), however, no research has been done to assess this scenario.

If the soil contact pathway is eliminated below 3 metres, human health exposure pathways will form the basis for remediation objectives. Human health pathways for Fractions 3 and 4 are set at RES (30,000 mg/kg). Vapour inhalation pathways will control Fractions 1 and 2. If individual jurisdictions allow vapour inhalation or other human health pathways to be screened out for certain land uses (e.g. Natural Areas in Alberta) and site characteristics allow groundwater protection pathways to be screened out, high concentrations could potentially be left below 3 m. Under this scenario, upward movement of volatile hydrocarbons may present a stress to overlying vegetation and soil invertebrates. No data is available to evaluate this exposure pathway.

Table 1. Rooting Depth for Common Agricultural and Forest Species.

Crop Species	Rooting Depth (m)	Method[a]	Reference
Agricultural Crops			
Barley	0.6 –1.8	Excavation	Weaver, 1926
Bean	0.9-1.2	Excavation	Weaver and Bruner, 1927
Bean	1.0	Minirhizotron	Merrill et al, 2002
Canola	1.14	Minirhizotron	Merrill et al, 2002
Canola	1.7[b]	Water Depletion	Nielsen, 1997
Corn	2.1-2.4	Excavation	Weaver, 1927
Corn	1.9	Water Depletion	Dardanelli et al, 1997
Oats	1.2-1.5	Excavation	Weaver, 1927
Oats	1.5	Water Depletion	Ragab et al, 1990
Pea	0.9	Excavation	Weaver and Bruner, 1927
Pea	0.99	Minirhizotron	Merrill et al, 2002
Potato	1.4	Excavation	Weaver, 1926
Rye	1.5	Excavation	Weaver, 1926
Safflower	1.64	Minirhizotron	Merrill et al, 2002
Soybean	0.99	Minirhizotron	Merrill et al, 2002
Sugar Beet	1.3-1.8	Excavation	Weaver, 1926
Dwarf Sunflower	1.0-1.8	Water Depletion	Angadi and Entz, 2002
Sunflower	1.45	Minirhizotron	Merrill et al, 2002
Sunflower	3.3	Water Depletion	Ragab et al, 1990
Sunflower	2.5-2.9	Water Depletion	Dardanelli et al, 1997
Spring Wheat	1.5	Excavation	Weaver, 1926
Spring Wheat	1.3	Excavation	Entz et al, 1992
Spring Wheat	1.23	Minirhizotron	Merrill et al, 2002
Winter Wheat	1.2	Excavation	Weaver, 1926
Winter Wheat	1.1	Excavation	Entz et al, 1992
Winter Wheat	1.45[c]	Water Depletion	Xue et al, 2003
Horticultural Crops			
Asparagus	3.0	Excavation	Weaver and Bruner, 1927
Beet	3.0	Excavation	Weaver and Bruner, 1927
Cabbage	2.4	Excavation	Weaver and Bruner, 1927
Carrot	3.0	Excavation	Weaver and Bruner,

Crop Species	Rooting Depth (m)	Method[a]	Reference
			1927
Cauliflower	1.4	Excavation	Weaver and Bruner, 1927
Cucumber	1.1	Excavation	Weaver and Bruner, 1927
Eggplant	2.1	Excavation	Weaver and Bruner, 1927
Garlic	0.75	Excavation	Weaver and Bruner, 1927
Horseradish	4.3	Excavation	Weaver and Bruner, 1927
Kohlrabi	2.6	Excavation	Weaver and Bruner, 1927
Leek	0.75	Excavation	Weaver and Bruner, 1927
Lettuce	1.8-2.3	Excavation	Weaver and Bruner, 1927
Onion	0.9	Excavation	Weaver and Bruner, 1927
Parsley	0.9	Excavation	Weaver and Bruner, 1927
Parsnip	2.7	Excavation	Weaver and Bruner, 1927
Pumpkin	1.8	Excavation	Weaver and Bruner, 1927
Radish	2.1	Excavation	Weaver and Bruner, 1927
Rhubarb	3.0	Excavation	Weaver and Bruner, 1927
Rutabaga	1.8	Excavation	Weaver and Bruner, 1927
Squash	1.8	Excavation	Weaver and Bruner, 1927
Strawberry	0.9	Excavation	Weaver and Bruner, 1927
Spinach	2.0	Excavation	Weaver and Bruner, 1927
Swiss Chard	2.0	Excavation	Weaver and Bruner, 1927
Tomato	1.3	Excavation	Weaver and Bruner, 1927
Turnip	1.7	Excavation	Weaver and Bruner, 1927

Crop Species	**Rooting Depth (m)**	**Method[a]**	**Reference**
Forage Crops			
Alfalfa	3-3.7	Excavation	Weaver, 1926
Alfalfa	3.6	Water Depletion	Mathers et al, 1975
Alfalfa	2.5	Water Depletion	Dardanelli et al, 1997
Bromegrass	1.7-2.0	Excavation	Weaver, 1927
Kentucky Bluegrass	0.9	Excavation	Weaver, 1954
Red Clover	2.5-3	Excavation	Weaver, 1926
Sweet Clover	1.5	Excavation	Weaver, 1926
White Clover	0.76	Excavation	Weaver, 1926
Forest			
Black Spruce	0.3 (frequent) 0.9 (maximum)	Excavation	Damman, 1971
Balsam Fir	0.5 (frequent) 0.9 (maximum)	Excavation	Damman, 1971
White Spruce – Subalpine Fir Overstory	0.8+	Excavation	Kimmins and Hawkes, 1978
White Spruce – Subalpine Fir Understory	0.8+	Excavation	Kimmins and Hawkes, 1978
Aspen – Jack Pine, sandy soil	1.3	Water Depletion	Strong and La Roi, 1983
Aspen – clay loam	0.95	Water Depletion	Strong and La Roi, 1983
White Spruce	1.2+	Excavation	Van Rees, 1997
Trembling Aspen	1.2+	Excavation	Van Rees, 1997
Jack Pine	1.2+	Excavation	Van Rees, 1997
Native Prairie			
Aster (*Aster ericoides*)	2.0	Excavation	Weaver, 1954
Blazing Star (*Liatris punctata*)	3.0	Excavation	Weaver, 1954
Blue Grama	0.9	Excavation	Weaver, 1954
Canada Goldenrod (*Solidago canadensis*)	3.0	Excavation	Weaver, 1954

Crop Species	Rooting Depth (m)	Method[a]	Reference
Canada Wild-Rye	0.6	Excavation	Weaver, 1954
Junegrass (*Koelaria cristata*)	0.5	Excavation	Weaver, 1954
Needlegrass (*Stipa spartea*)	0.9	Excavation	Weaver, 1954
Prairie Clover (*Petalostemum purpureum*)	1.8	Excavation	Weaver, 1954
Prairie Rose (*Rosa suffulta*)	6.0	Excavation	Weaver, 1954
Rough fescue grassland	1.2	Excavation	Coupland and Brayshaw, 1953
Western Wheatgrass (*Agropyron smithii*)	1.8	Excavation	Weaver, 1954
Wheatgrass-Junegrass grassland	1.5+	Excavation	Coupland et al, 1975

[a] The water depletion method uses measurements of soil water content to estimate the depth of root activity. The excavation method involves physically separating the roots from excavated soil. Minirhizotrons are transparent tubes inserted in the soil that allow direct observation of root growth.
[b] 92-95% water use from 1.2m
[c] Root penetration restricted at 1.45 m by cemented caliche layer.

Table 2. Root mass (grams) distribution for native prairie by soil horizon (Coupland and Brayshaw, 1953)

Horizon	*Festuca scabrella*	*Stipa spartea*	*Koelaria cristata*
A and AB (17 cm)	42.6	23.4	23.3
B (51 cm)	13.4	11.5	13.7
C or D (53 cm)	7.8	0.5	1.0

Table 3. Distribution of fine roots in White Spruce-Subalpine Fir (g/m2). (Kimmins and Hawkes, 1978)

Depth (cm)	Overstory	Understory
LFH	94	66.4
Ae	34	176.6
0-10[a]	40	152.1
10-20	7.7	30.5

20-30	2.2	30.4
30-40	7.1	19.5
40-50	1.2	9.6
50-60	1.4	0.2
60-70	1.8	2.4
70-80	1.6	0.2

[a] "0" denotes the bottom of the Ae horizon

Table 4. Distribution of roots (%) in a Luvisol in Boreal Mixed Wood species (Van Rees and Jackson, 1994)

Depth (cm)	White Spruce	Trembling Aspen	Grass	Other
LFH	51	55	44	52
0-15	26	15	31	19
60-120	15	9	3	10

Table 5. Water relations of winter wheat (Gregory et al, 1978).

Depth	April 9 – May 13		May 13 – June 17		June 17 – July 8[a]		July 8 – July 29	
	Root Biomass	Water Uptake	Root Biomass	Water Uptake	Root Biomass	Water Uptake	Root Biomass	Water Uptake
	(% of total)							
0-30	58	100	63	71	59	39	54	86
30-60	22	0	22	16	21	17	22	6
60-100	17	0	13	13	17	25	18	2
>100	3	0	2	0	3	19	6	6

[a] Dry period

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Appendix E: Cermak and Tindal (2006) Report

(in accompanying electronic file)

Appendix F: Bright (2006) Memo

(in accompanying electronic file)

Appendix G: F3 Recovery

The committee notes that there is considerable uncertainty surrounding the actual concentration of PHC in the soil to which the organisms are responding among the many data sets; we have thoroughly examined the reports and evidence from the study that formed the basis of the 1999 criterion, and we are satisfied that we cannot identify the degree to which analytical recovery contributed to the apparent loss of nominal. We are suggesting that there is evidence in the 1999 data of biodegradation during transit; the magnitude of this loss, vs. incomplete analytical recovery, cannot be identified. The committee agrees that the preponderance of evidence supports that the actual concentration of PHC in soil used to estimate the IC50's generated in 1999 were higher than calculated by adjustment for recovery; full recovery is possible as indicated by the Axiom report, as well as the interlaboratory CAEAL study. As the 1999 IC50's are being supplanted by data generated since that time, for which the recovery of the PHC's from the soil was nearly complete, the committee is recognizing that this issue is self-resolving.

Author	Elapsed Time (d) to extraction	Range of Nominal Concentration	Type of Soil	Method of Extraction	Method of Recovery Evaluation	Amalgamated Recovery	Analytical Recovery	Loss from Nominal
ESG 1999 (Wang)	6	6000 – 120,000 mg/kg	Chernozem (Delacour)	EC (hexane DCM triple extaction with sonication, and silica gel	Injected pure F3	31-67% (correlated with [PHC] and moisture in soil	-some, can't separate from loss from nominal	Indicated by ratio of nC17/pristane, that there was bio-loss during the 6d
Axiom (Tindal)	2-3 in transit 1, 25, 63	800 – 6000 mg/kg	Chernozem (Delacour) and Mineral subsoil	CCME and EC	Matrix spiked Chernozem soil with F3, as well as low OC mineral soil	100%	N/a	N/a
CAPP/PTAC (McCann)	<30	260 – 16,000 mg/kg	Chernozem (Delacour)	Not CCME (Soxhlet, gel permeation chromatography, alumina column separation into aromatics and aliphatics then CCME protocol for GC-FID)	Matrix spike: clean Chernozem soil spiked with F3	N/a	67%	0 – 23%
PTAC (Visser)	0 4-5 d	 12,000 mg/kg	Chernozem (Turner Valley) Coarse Textured (Richmound)	Alberta Env. method		 119%	N/a	0%

CAEAL Round Interlaboratory Study (Malle, 2002)	F1: 0 d F2, F3, F4: 0 – 42 d	F1: 680 – 920 mg/kg F2, F3, F4: 500 – 5870 mg/kg	Sandy loam, clay loam, and three pottery clays (Red Art clay, Ball clay, and Kaolin clay) γ-radiation for the purpose of sterilization	F1: purge and trap with FID F2, F3, F4: CWS method with no deviations	Matrix spiked clean soils with various commercial oil preparations	~100%	n/a	F1 in Soils and Ball Clay: <25% Relative Standard Deviation F2, F3, F4 in Soils and Ball clay: <12% Relative Standard Deviation