

Protecting Livestock

Answers to Frequently Asked Questions
about Livestock Exposure to Crude Oil
in Oilfield Operations

WEB Exhibit # 18a

Introduction

Livestock may be exposed to accidental releases of petroleum hydrocarbons at or near oil and natural gas exploration and production sites. Under certain circumstances, it may be necessary to evaluate the *risk* posed to livestock.

In *Risk-Based Screening Levels for the Protection of Livestock Exposed to Petroleum Hydrocarbons* by Pattanayek and DeShields [2004], and referred to herein as “API (2004),” API developed toxicity values and screening guidelines for evaluating risks to livestock from exposure to petroleum hydrocarbons. The report addressed how to: (1) determine whether livestock should be included in a risk evaluation and (2) estimate risks of petroleum hydrocarbon exposures to livestock.

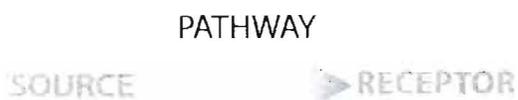
This booklet summarizes the key results of API (2004), describing ways livestock might be significantly exposed to petroleum hydrocarbons via a conceptual site model, and outlines how to make a screening level determination of whether or not livestock are at risk from the exposure.

Screening levels for livestock protection have been developed by other agencies (e.g., Canadian Council of Ministers of the Environment [CCME] and Alberta Environment). These values are either region-specific or cover limited constituents of petroleum hydrocarbons. API (2004) used a more generalized approach to develop conservative screening levels for petroleum hydrocarbons. The screening levels can be used to characterize risks to livestock across a variety of conditions. API (2004) describes the differences among API, CCME, and Alberta Environment and also provides an uncertainty analysis of the API approach.

A glossary provided on page 14 describes terms shown in *italic* throughout this booklet.

Conceptual Site Models

This booklet refers to the use of a **conceptual site model (CSM)** to identify potential sources, exposure pathways, and receptors. CSMs may be graphical or text-based; at a minimum, however, CSMs must identify a complete or potentially complete linkage between a source and a receptor to be considered in a risk assessment:

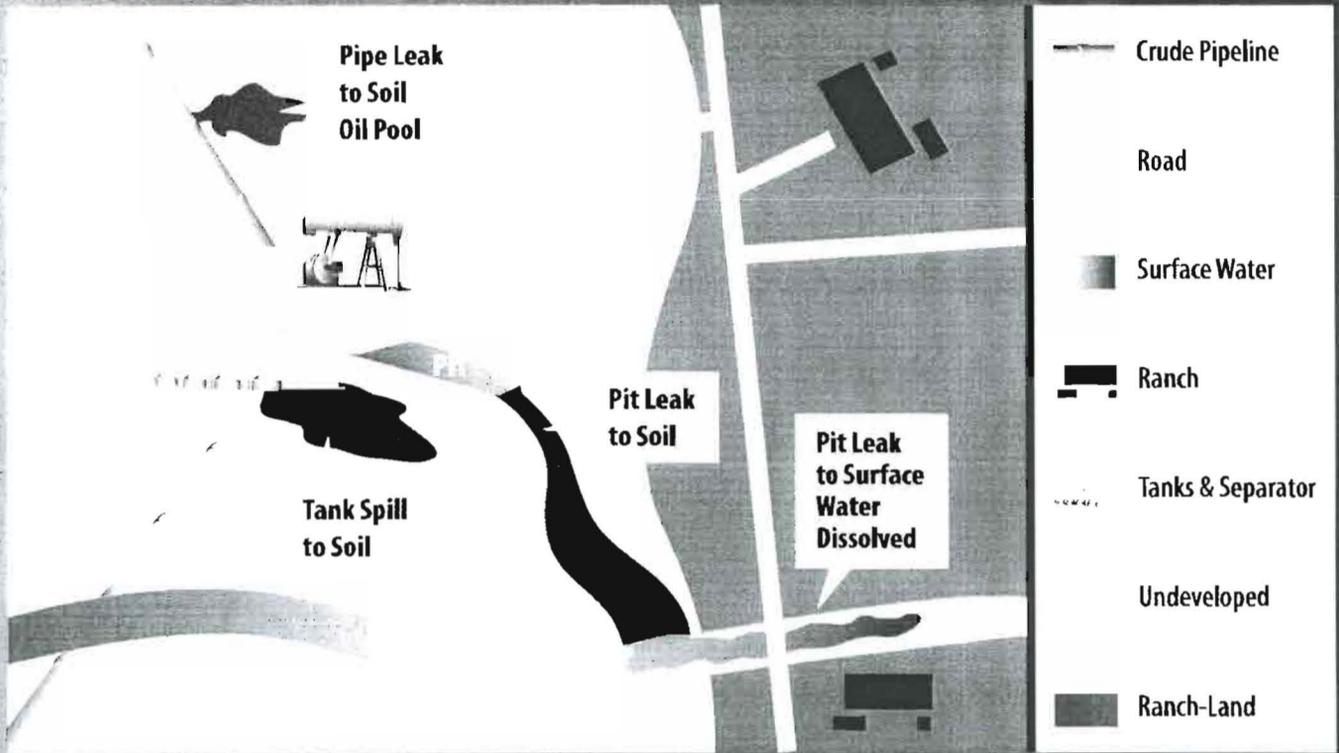


If a complete exposure pathway is not indicated by the CSM then further assessment is not necessary. If the linkage leads to an insignificant exposure, i.e. source concentrations less than the *risk-based screening levels (RBSLs)* for soil or water, the assessment indicates no unacceptable risk to the receptor. If constituent values are greater than RBSLs, further actions are taken to protect the receptor. The path forward could include a site-specific risk assessment, source treatment, source removal, source isolation, or land-use change.

WEB Exhibit #

186

Figure 1
Aerial view of a site with primary and secondary contaminant sources



What type(s) of animals are considered livestock?

API (2004) addresses dairy cattle, beef cattle, calves, sheep, goats, camels, and horses as receptors; therefore, they are considered livestock in this document. These are animals that forage in pasture areas. Species that are raised in more confined and controlled conditions, such as chickens or pigs, have less chance of exposure to petroleum hydrocarbons. Other species, such as llamas and oxen, could also be evaluated by following the approach outlined in API (2004). (Also, see text box: "Can Livestock RBSLs be Used for Wildlife?" on page 8).

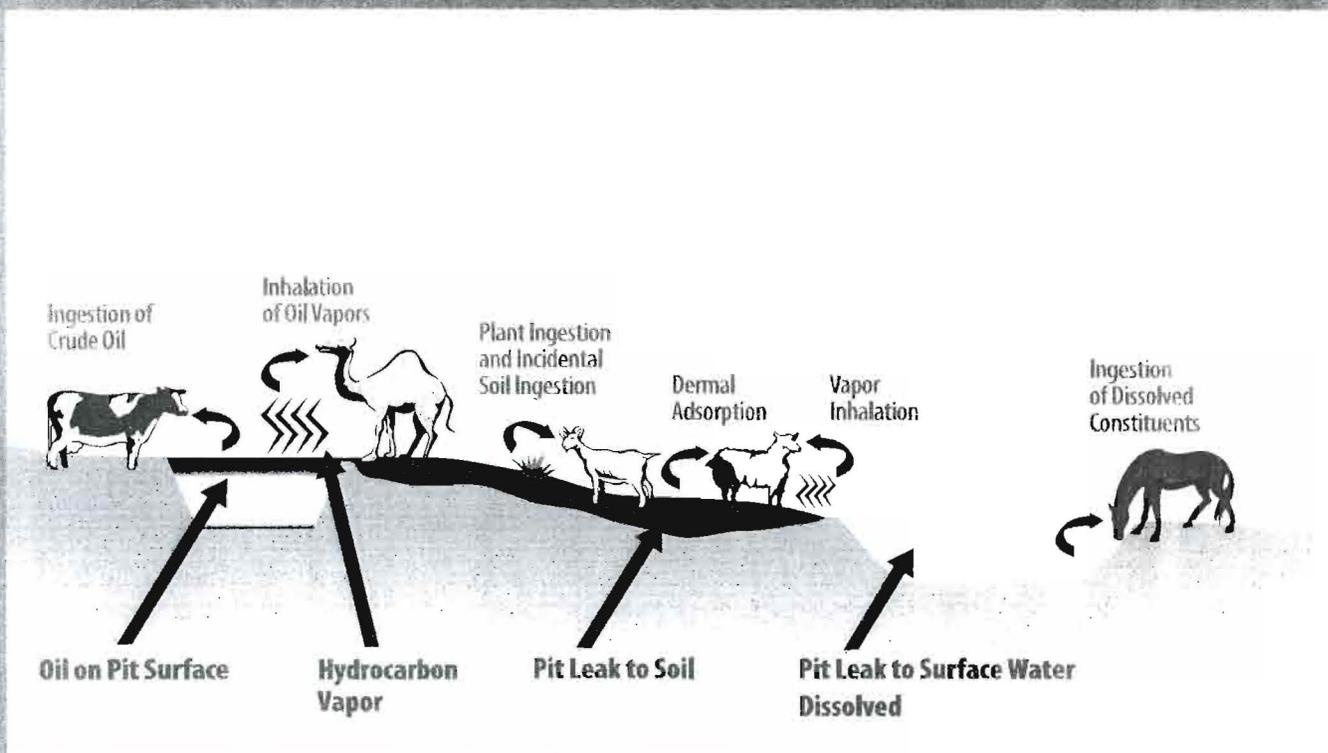
How are livestock typically exposed to crude oil?

Crude oil may be released to soil or water through accidental leaks and spills from primary sources such as equipment, pipelines, storage vessels, and transport vehicles. The resulting secondary sources are pools of crude oil, oil mixed in soil, dissolved constituents in water, and vapors in air (Figure 1).

Livestock can be exposed to petroleum hydrocarbons through incidental soil ingestion, water ingestion, direct ingestion of crude oil, inhalation, skin contact (dermal absorption), and indirectly through ingestion of contaminated plants (Figure 2). Based on information available in the scientific literature, the significant *exposure pathways* are incidental soil ingestion, water ingestion, and direct petroleum ingestion.

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Figure 2
 Potential source, pathways, and receptors addressed in API (2004)



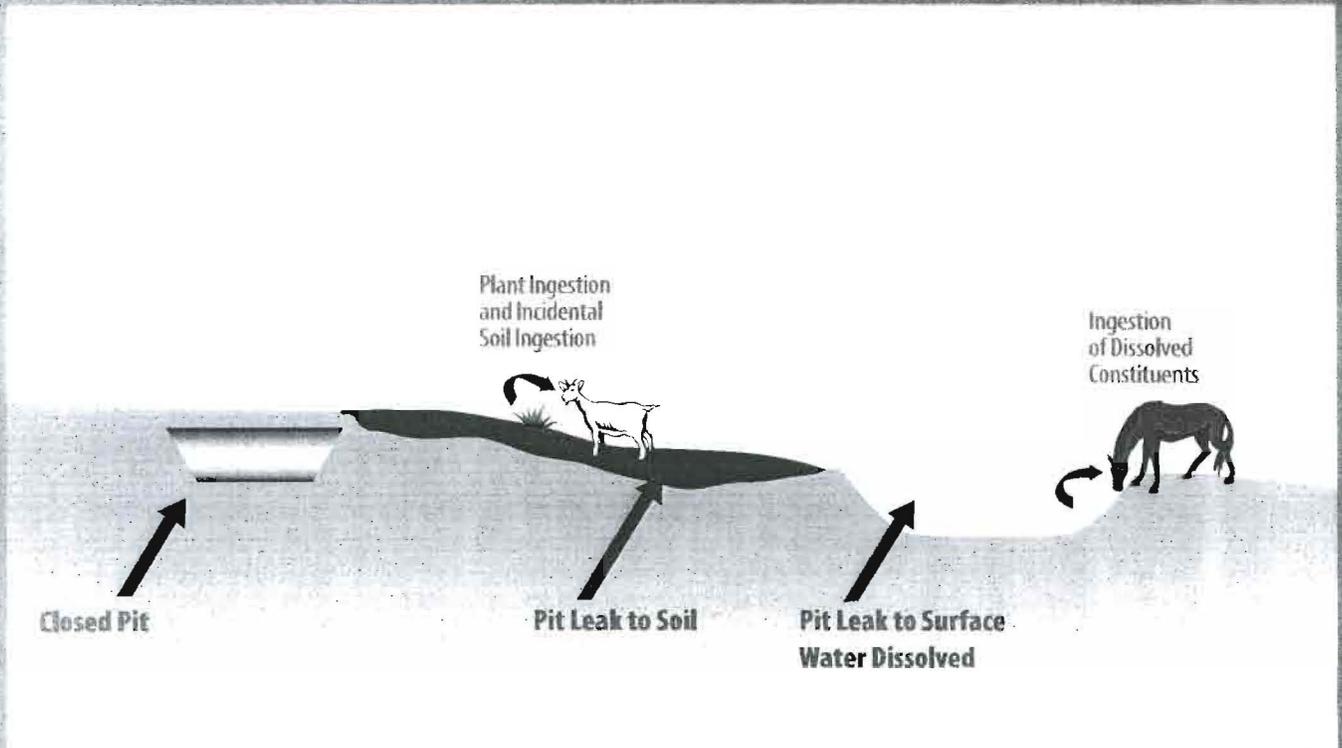
Livestock may consume soil inadvertently during grazing (Zach and Mayoh 1984; CCME 2000) or may intentionally ingest salty-tasting soil (Coppock *et al.* 1995). According to the CCME (2000), most of the petroleum hydrocarbon exposure in cattle is a result of contaminated surface-soil ingestion.

Chronic exposure through drinking water can be a significant exposure pathway for livestock (CCME 2000). The amount of water ingested by cattle varies according to age, physiological status (growth, fattening, pregnancy, lactation), diet composition, breed, size, and, for all animals, temperature (Agriculture and Agri-Food Canada 2001; National Research Council [NRC] 1988).

Cattle may directly ingest crude oil and other petroleum compounds because of curiosity (particularly young calves; Edwards 1985), i.e., drinking from pools created by piping failures (Edwards and Zinn 1979; Coppock *et al.* 1995; CCME 2000). Oil and natural gas industry guidance (API 1997) and many regulatory agencies (e.g., the Railroad Commission of Texas, 1993) stress the importance of removing free oil from the soil surface to prevent animal exposure.

WEB Exhibit # 18-d

Figure 3
Example conceptual site model showing significant exposure pathways at a site



How do I determine if livestock are at risk at a site?

The best way to start is to develop a *conceptual site model* (CSM). The CSM identifies complete and potentially complete exposure pathways (Fig. 3). If a complete significant pathway(s) does not exist for exposure of livestock to petroleum hydrocarbons, a screening-level risk evaluation for livestock is not necessary. By definition, if there is no significant exposure to a potentially toxic compound, there is no likelihood of significant unacceptable risk to the receptor from that compound.

If a significant exposure pathway exists, further screening-level assessment may be appropriate. A screening-level risk assessment uses a conservative approach to characterize potential risk to livestock exposed to petroleum hydrocarbons at a site. In short, concentrations of petroleum hydrocarbons in soil in milligrams per kilogram (mg/kg) and water in milligrams per liter (mg/L) at a site can be compared to *risk-based screening levels (RBSLs)* protective of livestock shown in Table 1.

WEB Exhibit # 18-e

Table 1
Risk-Based Screening Levels for Livestock

(Note: Depending on the composition of the oil, some RBSLs may exceed water solubility limits, therefore indicating that contaminated water cannot present a health risk unless free oil is present on the water.)

Livestock	Drinking Water Risk-Based Screening Levels (RBSLs; mg/L)						
	Crude Oil	Benzene	Toluene	Ethylbenzene	Xylene	LMW ¹ PAH	HMW ² PAH
Dairy Cattle	1,200	32.4	202	26.4	162	4.53	0.907
Beef Cattle	1,110	31.4	196	25.6	157	4.40	0.880
Calves	293	14.3	89.5	11.7	71.7	2.01	0.402
Sheep	855	40.5	253	33.1	203	5.68	1.14
Goats	622	34.8	217	28.4	174	4.87	0.974
Camels	7,670	202	1,260	165	1,000	28.3	5.65
Horses	2,760	74.3	464	60.6	371	10.4	2.08

Livestock	Soil Risk-Based Screening Levels (RBSLs; mg/kg)						
	Crude Oil	Benzene	Toluene	Ethylbenzene	Xylene	LMW PAH	HMW PAH
Dairy Cattle	47,200	1,270	7,950	1,040	6,370	178	35.7
Beef Cattle	44,900	1,270	7,900	1,030	6,330	177	35.5
Calves	44,900	2,200	13,700	1,790	11,000	308	61.5
Sheep	20,100	953	5,950	778	4,770	133	26.7
Goats	17,600	982	6,130	802	4,910	138	27.5
Camels	69,500	1,830	11,400	1,490	9,140	256	51.2
Horses	28,100	756	4,720	617	3,780	106	21.2

¹ Low molecular weight polycyclic aromatic hydrocarbons (LMW PAHs) are defined as PAHs with less than or equal to 3 rings.

² High molecular weight polycyclic aromatic hydrocarbons (HMW PAHs) PAHs are defined as PAHs with greater than or equal to 4 rings.

WEB Exhibit # 18 f



In general, what are livestock RBSLs and how are they developed?

RBSLs are threshold concentrations in soil and water, at or below which little-to-no likelihood of significant unacceptable risks to livestock are expected. API (2004) developed soil and drinking water RBSLs for crude oil, benzene, toluene, ethylbenzene, and xylenes (BTEX), low molecular weight polycyclic aromatic hydrocarbons (LMW PAHs), and high molecular weight polycyclic aromatic hydrocarbons (HMW PAHs) (see Table 1).

RBSLs for animals such as livestock are generally developed based on a risk assessment model integrating livestock exposures and toxicity values (i.e., *toxicity reference values* or TRVs). A description of how RBSLs were determined is provided on page 10 “How are livestock RBSLs calculated?” and covered in detail in API (2004).

How do I use RBSLs?

To use the RBSLs, site data are first evaluated to quantify the *Exposure Point Concentration* (EPC) to which livestock may be exposed under reasonable maximum exposure (RME) conditions. EPCs are concentrations of chemicals in site media (e.g., soil, water) to which livestock may be exposed. EPC can be calculated using USEPA guidelines (Section 6.5 of EPA 1989; EPA 2002) which outline the statistical methods that can be used and the considerations involved in choosing the appropriate statistical representation of exposure. The RME scenario represents an upper-bound estimate of exposure. As livestock generally graze over large areas, appropriate EPCs for the RME scenario could be the mean of the site data or the 95 percent upper confidence limit (95% UCL) of the mean concentration. According to the USEPA (EPA 1989), estimates of the RME EPC necessarily involve the use of professional judgment.

Next, soil or water EPCs for petroleum hydrocarbons can be compared to the media-specific and receptor-specific RBSLs (i.e., soil or drinking water) in Table 1 (see Example 1). If EPCs do not exceed RBSLs, then little to no likelihood of significant unacceptable risks can be expected. Conversely, if EPCs exceed RBSLs then a potential for unacceptable risks to livestock may be present and further assessment may be necessary.



WEB Exhibit # 18-g

Example 1
Application of RBSLs

Figure 3 is a graphical CSM for a site contaminated with weathered crude oil from previous exploration and production activities. Analysis of the soil and groundwater provided upper confidence limit (UCL) constituent concentrations as shown in Tables A-1 and A-2, respectively.

Table A-1
Comparing UCL Water Sample Analytical Result with RBSLs for Livestock Drinking Water

	Results Compared with Drinking Water RBSLs (mg/L)						
	Crude Oil	Benzene	Toluene	Ethylbenzene	Xylene	LMW PAH	HMW PAH
H₂O Sample	122	0.051	0.023	0.003	0.003	ND (0.001)	ND (0.001)
Goat RBSL	622	34.8	217	28.4	174	4.87	0.974
Horse RBSL	2,760	74.3	464	60.6	371	10.4	2.08
ND = Non-detect No Exceedances							

Table A-2
Comparing UCL Soil Sample Analytical Result with RBSLs for Livestock Soil Ingestion

	Results Compared with Soil RBSLs (mg/kg)						
	Crude Oil	Benzene	Toluene	Ethylbenzene	Xylene	LMW PAH	HMW PAH
Soil Sample	25,600	256	521	108	470	51	33.0
Goat RBSL	17,600	982	6,130	802	4,910	138	27.5
Horse RBSL	28,100	756	4,720	617	3,780	106	21.2
Exceedances are bold							

No further action is required for the drinking water exposure pathway because RBSLs were not exceeded.

The soil ingestion exposure pathway RBSL for crude oil was exceeded for horses and for HMW PAHs for goats and horses.

These results must be considered in the next step of decision-making. Exceeding a RBSL does not mean cleanup is required. It indicates that further risk assessment or some form of exposure mitigation is necessary.

WEB Exhibit # 18-h

Are livestock petroleum hydrocarbon RBSLs applicable to all types of crude oil releases?

In a screening-level risk assessment for any crude oil release, the RBSLs developed in API (2004) can be directly compared to crude oil concentrations, generally expressed as total petroleum hydrocarbon (TPH), at that site. TRVs for crude oil used to calculate the RBSLs were developed based on whole fresh, unweathered crude oil. TRVs and RBSLs for unweathered crude oil can be used for evaluating fresh spills and can be considered conservative screening values for weathered crude oil.

How can I obtain site-specific RBSLs?

The RBSLs developed for petroleum hydrocarbons in API (2004) were based on a generalized approach using conservative exposure parameters to characterize risks for a variety of livestock across a variety of conditions. However, site-specific RBSLs (also known as site-specific target levels or SSTLs) can be developed by substituting known site-specific site use factors (SUF) or exposure parameters (such as body weights, or ingestion rates for soil and water) in a subsequent evaluation if there is a need to refine the conservative assumptions used to calculate the RBSLs. Example 2 on the next page illustrates this procedure.

Can Livestock RBSLs be Used for Wildlife?

The RBSLs reported in API (2004) were developed specifically for the protection of livestock; therefore, they cannot be used directly for wildlife. However, a similar approach could be used to develop RBSLs for mammalian wildlife using wildlife-specific exposure parameters and body weight-scaled TRVs.

Livestock RBSLs for most of the individual petroleum hydrocarbons (i.e., BTEX and PAHs) were developed based on traditional laboratory mammalian toxicity studies as BTEX and PAH toxicity studies were not available for livestock. Toxicity values derived from small laboratory mammals were extrapolated, based on weight considerations, to a dose that

would be protective of livestock. Crude oil toxicity studies were available for livestock, and therefore, crude oil TRV and RBSLs were developed based on a cow study by Stober (1962).

If toxicity values are not available for a specific wildlife mammal, then available mammalian toxicological data can be used along with appropriate exposure parameters and TRVs to develop RBSLs for the species in question.

WEB Exhibit # 18-1

Example 2
SSTL Calculation

The previous example (Example 1) indicated that the soil ingestion exposure pathway RBSL for crude oil was exceeded for horses and for HMW PAHs for goats and horses. In this example, the development of a site-specific site use factor (SUF) is used to illustrate the calculation of site-specific target levels (SSTLs). The SUF represents the fraction of the exposure area for the receptor represented by the contamination area. API (2004) assumes a SUF of 1, i.e., the contaminated area is as large as the effective grazing area. In reality, only a portion of a total grazing area would be contaminated.

A field survey indicates that only 0.25 acre of these livestock's 2-acre range is affected by petroleum-related activities. Thus, the SUF is 0.125 instead of the default value of 1. Using the equations on page 10, "How are livestock RBSLs calculated?", SSTLs are determined using the site-specific SUF (i.e., RBSLs divided by the SUF). Likewise, other justifiable changes to default parameters could be used to calculate SSTLs.

Table B-1
Comparing UCL Soil Sample Analytical Result with Livestock Soil Ingestion SSTLs

	Results Compared with Soil SSTLs (mg/kg)						
	Crude Oil	Benzene	Toluene	Ethylbenzene	Xylene	LMW PAH	HMW PAH
Soil Sample	25,600	256	521	108	470	51	33
Goat RBSL	141,000	7,860	49,000	6,420	39,300	1,100	220
Horse RBSL	225,000	6,050	37,800	4,940	30,300	848	170
No Exceedances							

No further action is required for the livestock incidental soil ingestion exposure pathway because the SSTLs were not exceeded.

What if chemicals other than hydrocarbons (including BTEX and PAHs) are released?

This report focused on whole crude oil and its toxicologically important constituents (i.e., benzene, toluene, ethylbenzene, toluene [BTEX], and polycyclic aromatic hydrocarbons [PAHs]). Other chemicals, such as metals, can also be present in crude oil but are generally not found at high enough concentrations to provide a significant human health and ecological risk (Magaw et al., 1999).

Thus, metals were not addressed in API (2004). However, risks to livestock from metal exposure can be evaluated using a similar approach to that described on page 10 "How are Livestock RBSLs Calculated?" Toxicity values and RBSLs can be developed for metals to estimate potential risks to livestock using a similar approach to that described for petroleum hydrocarbons in API (2004).

WEB Exhibit # 18-j

How are Livestock RBSLs Calculated?

Livestock screening levels are risk-based and are developed based on the standard hazard quotient (HQ) equation used for estimating risks to human health and other ecological receptors (EPA 1997).

$$HQ = \frac{\text{Dose}}{\text{TRV}} \quad (\text{Equation 1a})$$

where:

TRV = Toxicity reference value in milligrams per kilogram body weight per day (mg/kg-bw/day)
 Dose = estimated daily dose of petroleum related hydrocarbons from ingestion (mg/kg-bw/day);
 and calculated using the following equation:

$$\frac{[(IR_{\text{soil}} \times C_{\text{soil}}) + (IR_{\text{water}} \times C_{\text{water}})] \times \text{SUF}}{\text{BW}} \quad (\text{Equation 1b})$$

where:

IR_{soil} = amount of soil incidentally ingested per day in dry weight (kg/day)
 IR_{water} = amount of water ingested per day (L/day)
 C_{soil} = concentration of constituent in soil or sediment (mg/kg dry weight)
 C_{water} = concentration of constituent in water (mg/L)
 SUF = site use factor (unitless)
 BW = body weight (kg)

Substituting Equation 1b for "Dose" in Equation 1a:

$$HQ = \frac{[(IR_{\text{soil}} \times C_{\text{soil}}) + (IR_{\text{water}} \times C_{\text{water}})] \times \text{SUF}}{\text{BW} \times \text{TRV}} \quad (\text{Equation 1c})$$

or

$$HQ = \frac{(\text{IR} \times \text{C}) \times \text{SUF}}{\text{BW} \times \text{TRV}} \quad (\text{Equation 1d})$$

To calculate RBSLs for a single medium (i.e., drinking water or soil), Equation 1d should be rearranged as shown in Equations 2a and 2b. Instead of estimating a HQ associated with a chemical concentration in water or soil and using the toxicity and exposure assumptions presented in Table 1 of the technical background report (API 2004), Equations 2a and 2b estimate a protective drinking water or soil concentration associated with a target HQ of 1.

Assuming target HQ = 1, SUF = 1, and rearranging Equation 1d, "C" becomes defined as the corresponding RBSL

Drinking-water RBSLs for livestock were calculated using the following equation:

$$\text{dwRBSL} = \frac{1 \times \text{BW} \times \text{TRV}}{\text{IR}_{\text{water}}} \quad (\text{Equation 2a})$$

where:

- 1 = target hazard quotient; unitless
- dwRBSL = drinking water RBSL in milligrams per liter (mg/L)
- IR_{water} = water ingestion rate in liters per day (L/day); to be conservative, the summer IR_{water} value from Table 1 is used
- BW = Body weight in kilograms (kg)
- TRV = Toxicity reference value in milligrams per kilogram body weight per day (mg/kg-bw/day)

Incidental soil ingestion RBSLs for livestock were calculated using the following equation:

$$\text{soilRBSL} = \frac{1 \times \text{BW} \times \text{TRV}}{\text{IR}_{\text{soil}}} \quad (\text{Equation 2b})$$

where:

- 1 = target hazard quotient; unitless
- soilRBSL = soil RBSL in milligrams per kilogram dry weight (mg/kg)
- IR_{soil} = soil ingestion rate in kilograms per day (kg/day)
- BW = body weight in kilograms (kg)
- TRV = toxicity reference value in milligrams per kilogram body weight per day (mg/kg-bw/day)

The TRVs developed in API (2004) are summarized as follows:

Livestock	Soil Risk-Based Screening Levels (RBSLs; mg/kg)						
	Crude Oil	Benzene	Toluene	Ethylbenzene	Xylene	LMW PAH	HMW PAH
Dairy Cattle	211	5.70	35.6	4.65	28.5	0.798	0.160
Beef Cattle	211	5.95	37.1	4.86	29.8	0.833	0.167
Calves	211	10.30	64.5	8.43	51.7	1.450	0.289
Sheep	211	10.00	62.5	8.17	50.1	1.400	0.280
Goats	211	11.80	73.6	9.62	58.9	1.650	0.330
Camels	211	5.55	34.6	4.53	27.8	0.777	0.155
Horses	211	5.67	35.4	4.63	28.4	0.794	0.159

How do livestock RBSLs compare to human health RBSLs?

The toxicity values and guidelines for crude oil developed by API (2004) for soil ingestion in livestock are comparable to the recommended human health RBSLs for sites affected with crude oils. The suggested RBSLs for human residential and non-residential scenarios are the 95th percentile values (for all exposure pathways) of 2,800 mg/kg and 41,300 mg/kg, respectively (McMillen et al., 2001). Similarly, a comparable TPH screening level of 10,000 parts per million (ppm) is generally accepted as protective of plants (Hamilton et al., 1999).

How do API livestock RBSLs differ from levels calculated by other groups?

TRVs, drinking water and soil screening levels for the protection of livestock exposed to petroleum compounds have been developed by two agencies, the Canadian Council of Ministers of the Environment (CCME) and Alberta Environment. Differences between calculated API and Canadian screening levels result from selection of constituents and guidelines considered, calculation errors, and the Canadian agencies' use of uncertainty, "protection," and "allocation" factors. Differences among the Canadian guidelines (including constituents and guidelines considered) and their limitations are described in the text box "CCME Canada-Wide Standards (CWS; CCME 2000) and Alberta Environment (2001)."



WEB Exhibit # 18m

CCME Canada-Wide Standards (CWS; CCME 2000) and Alberta Environment (2001)

The Canada-Wide Standards for petroleum hydrocarbons present TRVs (referred to as “Daily Threshold Effects Dose” or DTED) and drinking water RBSLs (referred to as “Reference Concentration” or RfC) for only whole oil and four fractions of crude oil (CCME 2000). These guidelines present levels that CCME considers protective under four generic land uses: agricultural, residential, commercial, and industrial. TRVs for livestock were developed based on Stober (1962), in an approach similar to that used by API. CCME and API used a similar approach to calculate drinking water RBSLs as well. However, a calculation error by CCME resulted in an order of magnitude, lower drinking-water screening level than that developed by API.

Alberta Environment set water RBSLs (referred to as “watering guidelines”) and soil RBSLs (referred to as “soil quality guidelines” or SQG) for petroleum hydrocarbons (crude oil fractions and BTEX) considered to be protective of livestock health (Alberta Environment 2001a; 2001b). Crude oil TRVs for livestock were adopted from CCME. For BTEX, TRVs were developed using an approach similar to that described in API (2004). Soil and water RBSLs reflect exposure parameters and “other” protection factors specific to Alberta.

CCME and Alberta Environment toxicity values and guidelines are presented in Table 8 of API (2004).

Differences between the CCME and Alberta Environment and the API approach as well as limitations to these approaches are summarized below:

Differences/Limitations	CCME Canada Wide Standards	Alberta Environment
TRV Development	TRVs for whole oil and four crude oil fractions were developed.	Crude oil TRVs were adopted from CCME. BTEX TRVs were developed.
Chemical Constituents	Only drinking water screening levels for whole oil and four crude oil fractions were developed for one livestock receptor (cattle).	Added soil and drinking water screening levels for BTEX and PAHs and soil screening levels for crude oil for one livestock receptor (cattle).
Uncertainty and Other Factors	An allocation factor (AF) of 0.2 was used to adjust toxicity values to account for multiple exposure pathways and media (air, soil, water, food, and consumer products), whereas the guideline values are for single pathways. The AF of 0.2 assumed that livestock can be equally exposed by all five potentially complete exposure pathways. However, dermal and inhalation pathways are expected to be minor. Additionally, not all sites will have both water and soil exposures. This likely results in an overly conservative RBSL.	In addition to the use of an AF of 0.2, a protection factor of 0.75 was used to prevent livestock from being exposed to more than 75% of the TRV. This is likely overly conservative.
Fractionation Approach	The fractionation approach used by CCME is not necessarily applicable or appropriate at all sites.*	The fractionation approach used by CCME and carried over by Alberta Environment is not necessarily applicable or appropriate at all sites.*
Additional Guidelines Developed	None	Two types of water quality guidelines were developed: <i>exposure point guidelines</i> for water to which receptors are actually exposed and <i>groundwater quality guidelines</i> to assess acceptable concentrations of chemicals in groundwater were also developed using fate and transport models.
Mathematical Errors	There was an order of magnitude error in calculating the RfC value by CCME; the RfC value should actually be 231 mg/L instead of 23 mg/L (this error was acknowledged by CCME; personal communication with Ted Nason September 10, 2002).	The error in the CCME RfC calculation is propagated in the Alberta Environment document.

* In this report, a toxicity value was developed for whole (i.e. fresh) crude oil. As fresh crude oil is more toxic than weathered oil, these values can be considered conservative screening values for weathered products.

WEB Exhibit # 18n

Glossary

Chronic exposure: A long-term contact between a receptor and a chemical that could result in a sub-lethal or permanent adverse effect.

Conceptual site model (CSM): A written description and/or visual representation of predicted relationships between receptors and the chemicals and/or stressors to which they may be exposed.

Exposure pathway: How a receptor comes in contact with a chemical and/or media.

Exposure point concentrations (EPC): The concentration of a chemical that a receptor is exposed to over a chronic exposure period.

Hazard quotient (HQ): The chemical-specific ratio of the dose to the toxicity value.

Receptor: The species, population, community, habitat, etc. that may be exposed to a chemical.

Risk: The likelihood of a harmful effect to a receptor based on the existence and magnitude of a hazard and exposure of the receptor to the hazard.

Risk assessment: A method to evaluate the potential adverse effects of chemicals or other stressors on receptors.

Risk-based screening levels (RBSLs): Chemical-specific concentrations in environmental media that are considered protective of health. Usually they are derived from the generally accepted risk equations by specifying an acceptable target risk level and rearranging the equations to determine the chemical concentration in the environmental medium of interest that achieves this risk level.

Site-specific target levels (SSTLs): RBSLs calculated using site-specific values rather than generally accepted defaults.

Toxicity reference value (TRV): A dose of a chemical at or above which a toxic response occurs in the receptor.

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