Risk-Based Screening Levels for the Protection of Livestock Exposed to Petroleum Hydrocarbons

Regulatory Analysis and Scientific Affairs

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FOREWORD

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1. Executive Summary

Livestock may be exposed to accidental releases of petroleum hydrocarbons at or near exploration and production sites and, in these cases, there may be a need to estimate potential risks to these receptors. A framework was developed to 1) determine when livestock should be included in a risk evaluation and 2) estimate risks of petroleum hydrocarbon exposure to livestock. A conceptual site model (CSM) was developed to assess whether complete and significant exposure pathways for livestock exist at a site.

To estimate potential risks in this screening-level risk assessment, toxicity reference values (TRVs) and drinking water and soil risk-based screening levels (RBSLs) for petroleum hydrocarbons, including: crude oil; benzene, toluene, ethylbenzene, and xylene (BTEX); and polycyclic aromatic hydrocarbons (PAHs) were developed for livestock. TRVs and RBSLs were developed for the protection of a variety of livestock including dairy cattle, beef cattle, calves, sheep, goats, camels, and horses.

TRVs for petroleum hydrocarbons were based on available toxicity values from studies conducted on livestock, if available, or on small mammals extrapolated to be protective of livestock evaluated in this report. RBSLs were calculated for the two complete and significant exposure pathways identified in the CSM, drinking water ingestion and incidental soil ingestion. Drinking water and soil RBSLs were calculated based on the TRVs and the selected exposure assumptions for the livestock.

The TRVs and RBSLs developed for this framework were comparable to human health RBSLs as shown in the following table:

<table>
<thead>
<tr>
<th>Livestock</th>
<th>Crude Oil</th>
<th>Benzene</th>
<th>Toluene</th>
<th>Ethylbenzene</th>
<th>Xylene</th>
<th>LMW PAH</th>
<th>HMW PAH</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dairy Cattle</td>
<td>211</td>
<td>5.70</td>
<td>35.6</td>
<td>4.65</td>
<td>28.5</td>
<td>0.798</td>
<td>0.160</td>
</tr>
<tr>
<td>Beef Cattle</td>
<td>211</td>
<td>5.95</td>
<td>37.1</td>
<td>4.86</td>
<td>29.8</td>
<td>0.833</td>
<td>0.167</td>
</tr>
<tr>
<td>Calves</td>
<td>211</td>
<td>10.3</td>
<td>64.5</td>
<td>8.43</td>
<td>51.7</td>
<td>1.45</td>
<td>0.289</td>
</tr>
<tr>
<td>Sheep</td>
<td>211</td>
<td>10.0</td>
<td>62.5</td>
<td>8.17</td>
<td>50.1</td>
<td>1.40</td>
<td>0.280</td>
</tr>
<tr>
<td>Goats</td>
<td>211</td>
<td>11.8</td>
<td>73.6</td>
<td>9.62</td>
<td>58.9</td>
<td>1.65</td>
<td>0.330</td>
</tr>
<tr>
<td>Camels</td>
<td>211</td>
<td>5.55</td>
<td>34.6</td>
<td>4.53</td>
<td>27.8</td>
<td>0.777</td>
<td>0.155</td>
</tr>
<tr>
<td>Horses</td>
<td>211</td>
<td>5.67</td>
<td>35.4</td>
<td>4.63</td>
<td>28.4</td>
<td>0.794</td>
<td>0.159</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Livestock</th>
<th>Crude Oil</th>
<th>Benzene</th>
<th>Toluene</th>
<th>Ethylbenzene</th>
<th>Xylene</th>
<th>LMW PAH</th>
<th>HMW PAH</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dairy Cattle</td>
<td>1,199</td>
<td>32.4</td>
<td>202</td>
<td>26.4</td>
<td>162</td>
<td>4.53</td>
<td>0.907</td>
</tr>
<tr>
<td>Beef Cattle</td>
<td>1,114</td>
<td>31.4</td>
<td>196</td>
<td>25.6</td>
<td>157</td>
<td>4.40</td>
<td>0.880</td>
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<tr>
<td>Calves</td>
<td>293</td>
<td>14.3</td>
<td>89.5</td>
<td>11.7</td>
<td>71.7</td>
<td>2.01</td>
<td>0.402</td>
</tr>
<tr>
<td>Sheep</td>
<td>855</td>
<td>40.5</td>
<td>253</td>
<td>33.1</td>
<td>203</td>
<td>5.68</td>
<td>1.14</td>
</tr>
<tr>
<td>Goats</td>
<td>622</td>
<td>34.8</td>
<td>217</td>
<td>28.4</td>
<td>174</td>
<td>4.87</td>
<td>0.974</td>
</tr>
<tr>
<td>Camels</td>
<td>7,673</td>
<td>202</td>
<td>1,259</td>
<td>165</td>
<td>1,009</td>
<td>28.3</td>
<td>5.65</td>
</tr>
<tr>
<td>Horses</td>
<td>2,763</td>
<td>74.3</td>
<td>464</td>
<td>60.6</td>
<td>371</td>
<td>10.4</td>
<td>2.08</td>
</tr>
<tr>
<td>Livestock</td>
<td>Crude Oil</td>
<td>Benzene</td>
<td>Toluene</td>
<td>Ethylbenzene</td>
<td>Xylene</td>
<td>LMW PAH</td>
<td>HMW PAH</td>
</tr>
<tr>
<td>------------</td>
<td>-----------</td>
<td>---------</td>
<td>---------</td>
<td>--------------</td>
<td>--------</td>
<td>---------</td>
<td>---------</td>
</tr>
<tr>
<td>Dairy Cattle</td>
<td>47,151</td>
<td>1,273</td>
<td>7,946</td>
<td>1,039</td>
<td>6,367</td>
<td>178</td>
<td>35.7</td>
</tr>
<tr>
<td>Beef Cattle</td>
<td>44,894</td>
<td>1,266</td>
<td>7,901</td>
<td>1,033</td>
<td>6,331</td>
<td>177</td>
<td>35.5</td>
</tr>
<tr>
<td>Calves</td>
<td>44,894</td>
<td>2,198</td>
<td>13,715</td>
<td>1,794</td>
<td>10,990</td>
<td>308</td>
<td>61.5</td>
</tr>
<tr>
<td>Sheep</td>
<td>20,095</td>
<td>953</td>
<td>5,949</td>
<td>778</td>
<td>4,767</td>
<td>133</td>
<td>26.7</td>
</tr>
<tr>
<td>Goats</td>
<td>17,583</td>
<td>982</td>
<td>6,129</td>
<td>802</td>
<td>4,911</td>
<td>138</td>
<td>27.5</td>
</tr>
<tr>
<td>Camels</td>
<td>69,522</td>
<td>1,829</td>
<td>11,412</td>
<td>1,492</td>
<td>9,144</td>
<td>256</td>
<td>51.2</td>
</tr>
<tr>
<td>Horses</td>
<td>28,133</td>
<td>756</td>
<td>4,719</td>
<td>617</td>
<td>3,782</td>
<td>106</td>
<td>21.2</td>
</tr>
</tbody>
</table>

mg/kg-bw/day = milligrams per kilogram body weight per day. 
mg/L = milligrams per liter. 
mg/kg = milligrams per kilogram. 
LMW PAH = low molecular weight polycyclic aromatic hydrocarbon. 
HMW PAH = high molecular weight polycyclic aromatic hydrocarbon.
2. Introduction

Consumption of petroleum hydrocarbons by livestock has been found to lead to a range of health problems, including neurotoxicity (Coppock et al. 1995; Khan et al. 1995), fetal toxicity (Coppock et al. 1995), damage to the gastrointestinal tract (Coppock et al. 1996), respiratory system, kidney, and liver (Meadows and Waltner-Toews 1979; Edwards 1985a; Coppock et al. 1995; Coppock et al. 1996; Stober 1962). Petroleum ingestion has also been linked to anorexia (Edwards and Zinn 1979), lethargy (Meadows and Waltner-Toews 1979; Edwards 1985b), and fatal poisoning in cattle (Edwards and Zinn 1979; Meadows and Waltner-Toews 1979; Edwards and Gregory 1991).

The purpose of this study was to develop toxicity values and screening guidelines for evaluating risks to livestock from exposure to petroleum hydrocarbons. This report addresses how to: (1) determine whether livestock should be included in a risk evaluation, and (2) estimate risks of petroleum hydrocarbon exposures to livestock.

In this report, the approach used to develop toxicity values and screening guidelines for livestock from petroleum hydrocarbon exposures was divided into two steps:

- The first step included evaluation of the potential for exposure through the development of a conceptual site model (CSM).
- The second step included development of Toxicity Reference Values (TRVs) and Risk-Based Screening Levels (RBSLs) for the protection of livestock.

This report focused on whole crude oil and its toxicologically important constituents (i.e. benzene, toluene, ethylbenzene, and xylene [BTEX] and polycyclic aromatic hydrocarbons [PAHs]). Metals can also be present in petroleum products, but they are generally not found at high enough concentrations to provide a significant health risk (Magaw et al., 1999) and therefore metals are not addressed in this report.

The approach presented herein is consistent with a screening-level risk assessment and used a conservative approach to determine potential risks to receptors by comparing exposure levels of petroleum hydrocarbons from a site to petroleum hydrocarbon threshold levels protective of livestock. Although threshold values for the protection of livestock have been developed by some 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. In this study, a more generalized approach was used to develop conservative threshold values such as TRVs (i.e., toxicity values) and RBSLs (i.e., guidelines) for petroleum hydrocarbons that can be used to characterize risks to livestock across a variety of conditions.
3. Conceptual Site Model

A conceptual site model (CSM) identifies complete and potentially complete exposure pathways and receptors to be considered in a risk assessment. If no complete significant pathway(s) exist for exposure of livestock to petroleum hydrocarbons, a screening-level risk evaluation for livestock is not necessary. By definition, if there is little to no significant exposure to a potentially toxic compound, there is little to no likelihood of significant unacceptable risk to the receptor from that compound. A CSM was developed as presented in Figure 1 to assess the potential for exposures to livestock and the need for a risk evaluation. Components of a CSM generally include receptor evaluation and exposure pathway evaluation, which are described below.

3.1 Receptor Evaluation

Livestock that are potentially vulnerable to toxic effects of petroleum hydrocarbons include animals that could ingest significant quantities of soil, water, and/or food in oil-contaminated areas. Access to the contaminated areas is key; cattle, sheep, goats, and horses that forage in pasture areas are more likely to be potential receptors, while species that are raised in more confined and controlled conditions, such as chickens or pigs, would have less chance of exposure to petroleum hydrocarbons. Outside of the United States, other types of livestock animals may also be exposed to petroleum compounds, such as camels, llamas, oxen, etc. It was assumed that exposures to these receptors would be similar to those of typical livestock in the United States based on similarities in body weights and feeding habits.

3.2 Pathway Evaluation

The pathways by which livestock could be exposed to petroleum hydrocarbons are incidental soil ingestion, water ingestion, and direct ingestion, inhalation, dermal absorption, and plant ingestion. Based on available information, the primary exposure pathways considered significant in the exposure model as shown in the CSM (Figure 1) included incidental soil ingestion, water ingestion, and direct petroleum product ingestion. Inhalation, dermal absorption, and plant ingestion were considered minor pathways for petroleum hydrocarbons (CCME 2000). The exposure pathways listed above are described in more detail below.

3.2.1 Soil Ingestion

Soil can comprise a substantial proportion of the livestock diet. 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), cattle are exposed to petroleum hydrocarbons primarily through consumption of contaminated soils, particularly during grazing. The authors state that the majority of petroleum hydrocarbon exposure in cattle is due to ingestion of surface soils.

3.2.2 Water 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).
Figure 1. Conceptual Site Model for Livestock Exposed to Petroleum Hydrocarbons
3.2.3 Direct Ingestion
Cattle may directly ingest crude oil and other petroleum compounds from pools of oil formed by leaking pipelines or storage tanks (Edwards and Zinn 1979; Coppock et al. 1995; CCME 2000) due to curiosity (particularly in young calves; Edwards 1985b), or to add salt to their diet (Edwards 1985b, Coppock et al. 1995). Reported cases include steers consuming petroleum distillate, drinking from a slush pit, and drinking petroleum from puddles near a tank battery (Edwards and Zinn 1979). 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 accumulations on the ground that animals could potentially ingest.

3.2.4 Dermal Absorption
Dermal absorption of petroleum hydrocarbons in livestock is considered a minor exposure pathway because of their thick coats (CCME 2000). While methods are available to assess dermal exposure to humans, data necessary to estimate dermal exposure are generally not available for livestock or wildlife (EPA 1993). Additionally, dermal exposure has been shown to be negligible for most terrestrial mammals (EPA 2000).

3.2.5 Inhalation
According to CCME (2000), inhalation of petroleum hydrocarbons is also a minor exposure pathway for livestock. Inhalation of petroleum hydrocarbons was assumed to be negligible for two reasons: (1) due to the assumed presence of vegetation on grazing lands, exposure of contaminated surface soils to winds and resulting aerial suspension of contaminated dust particulates would be minimized, and (2) most volatile organic compounds (VOCs)—the contaminants most likely to present a risk through inhalation—get rapidly diluted and dispersed in ambient air, making significant exposure to VOCs through inhalation unlikely. In situations where inhalation exposure is believed to be more significant, evaluation of this pathway should be considered.

3.2.6 Plant Ingestion
Exposure to petroleum hydrocarbons through ingestion of plants is considered a minor pathway (CCME 2000). The authors explain that although the ingestion rates of plants are high for livestock, plants are considered a minor contributor to this proportion, due to the limited phytoaccumulation (i.e., a process by which plants accumulate contaminants into roots and above ground shoots or leaves) potential of petroleum hydrocarbons (CCME 2000; Alberta Environment 2001a).

3.3 Summary of the CSM for Livestock
If the CSM can identify any complete and significant exposure pathway(s) for livestock receptors at a site, then the next step would be to conduct a screening-level risk assessment. However, another factor to consider in determining whether there is need to assess livestock risks is the size of the contaminated area or release relative to the size of the grazing area. This is referred to as a site use factor (explained further in the following section). A small affected area (e.g. less than one acre) is unlikely to result in significant risks to herds of livestock and may not warrant a screening-level risk assessment (Texas Natural Resource Conservation Commission [TNRCC] 2000 and Pennsylvania Department of Environmental Protection [PADEP] 1998). Cumulative risks can be estimated for livestock receptors exposed to petroleum hydrocarbons via multiple exposure pathways (for example, via soil ingestion and water ingestion at a site).
A screening-level risk assessment uses a conservative approach to determine any potential risk to receptors exposed to contaminants at a site which includes comparing exposure levels of contaminants from a site to appropriate threshold values (i.e., toxicity values and guidelines). To characterize potential risks to livestock, petroleum hydrocarbon exposure levels from a site can be compared to petroleum hydrocarbon threshold levels protective of livestock.

As explained earlier, the approach described in this report is general, not site-specific. Therefore, threshold values were developed for the primary exposure pathways: 1) drinking water ingestion, and 2) incidental soil ingestion. Although, direct ingestion was also considered a significant exposure pathway (Figure 1), site-specific parameters are required to develop threshold values for this pathway and therefore, were not addressed in this report.
4. Toxicity Reference Values and Risk-Based Screening Levels

A Toxicity Reference Value (TRV) is a daily dose of a chemical expressed in milligrams of chemical per kilogram of body weight of the livestock receptor per day (mg/kg-bw/day) and represents a concentration associated with an effect level or threshold. TRVs were developed for the protection of livestock at the population level (i.e., herd) of ecological organization and are generally doses at or below which no adverse health effects (e.g., mortality, growth, and reproduction) to the indicator species are expected, even if exposure occurs over an extended duration. TRVs for livestock in this report were developed from the exposure assumptions in Table 1 and available toxicological data presented in Table 2.

Risk-Based Screening Levels (RBSLs) are threshold concentrations in site media (e.g., soil, water, and air) at or below little-to-no likelihood of significant unacceptable risks to livestock are expected. RBSLs were developed based on a food-web model integrating livestock exposures and TRVs. In this framework, livestock RBSLs were developed for complete and significant exposure pathways, which included drinking water RBSLs expressed in milligrams per liter (mg/L) and soil RBSLs expressed in milligrams per kilogram (mg/kg). The following sections describe the exposure and effects assessments used in this report to develop livestock TRVs and RBSLs for complete and potentially significant exposure pathways.

4.1 Exposure Assessment

As discussed previously, the main exposure pathways for cattle, sheep, goats, camels, horses, and other potential livestock receptors are incidental soil ingestion, water ingestion, and direct ingestion. Direct ingestion of chemicals is generally not addressed in a food-web model; however, this pathway should be assessed on a site-specific basis if considered potentially complete. Exposures are generally measured by estimating the intake rates for livestock in kilograms per day (kg/day) or liters per day (L/day) and converting them to doses.

Dose calculation models provide a method of conservatively estimating exposure through the food chain. To ensure conservatism in the overall exposure estimates, it is recommended that the lesser of either the 95% upper confidence limit (UCL) of the mean concentration or the maximum detected concentration in site media (i.e., soil and water) be selected to represent the exposure point concentration (EPC). As dose estimation through modeling generally requires conservative exposure assumptions, exposures measured through modeling tend to be overestimated when compared with actual exposures. The equation used to calculate daily ingested petroleum hydrocarbon dose for livestock was as follows:

\[
Dose = \frac{(IR_{soil} \times C_{soil}) + (IR_{water} \times C_{water}) \times SUF}{BW} \tag{Equation 1}
\]

Where:

\[
\begin{align*}
Dose & = \text{estimated daily dose of petroleum related hydrocarbons from ingestion (mg/kg-bw/day)} \\
IR_{soil} & = \text{amount of soil incidentally ingested per day in dry weight (kg/day)} \\
IR_{water} & = \text{amount of water ingested per day (L/day)} \\
C_{soil} & = \text{concentration of constituent in soil or sediment (mg/kg dry weight)} \\
C_{water} & = \text{concentration of constituent in water (mg/L)} \\
SUF & = \text{site use factor (unitless)} \\
BW & = \text{body weight (kg)}
\end{align*}
\]
Table 1. Exposure Assumptions for Livestock

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Data</th>
<th>Source</th>
<th>Data</th>
<th>Source</th>
<th>Data</th>
<th>Source</th>
<th>Data</th>
<th>Source</th>
<th>Data</th>
<th>Source</th>
<th>Data</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Body Weight (kg)</td>
<td>540</td>
<td>MRBC, 2001; average of the range 480 to 680 kg</td>
<td>484</td>
<td>Lyons et al., 1999. See footnote 1.</td>
<td>50.0</td>
<td>MRBC, 2000; average weight of growing calves range is 25 - 75 kg. See footnote 1.</td>
<td>56.7</td>
<td>Lyons et al., 1999. See footnote 1.</td>
<td>29.5</td>
<td>Lyons et al., 1999; based on Spanish goats</td>
<td>600</td>
<td>Average body weight from a general weight based search and from Gilah et al., 1990.</td>
</tr>
<tr>
<td>Composition of Diet</td>
<td>Estimated percent soil</td>
<td>0.179</td>
<td>Percentage of dry matter intake; most conservative value; Absalom and Thornton 1994. See footnote 2.</td>
<td>0.188</td>
<td>Percentage of dry matter intake; most conservative value; Kennedy and Strong 1992. See footnote 2.</td>
<td>0.188</td>
<td>Percentage of dry matter intake; most conservative value; Kennedy and Strong 1992. See footnote 2.</td>
<td>0.300</td>
<td>Conservative assumption. See footnote 2.</td>
<td>0.300</td>
<td>Conservative assumption. See footnote 2.</td>
<td>0.300</td>
</tr>
<tr>
<td>Estimated percent forage</td>
<td>Calculated; assuming main food item</td>
<td>0.821</td>
<td>Calculated; assuming main food item</td>
<td>0.821</td>
<td>Calculated; assuming main food item</td>
<td>0.700</td>
<td>Calculated; assuming main food item</td>
<td>0.700</td>
<td>Calculated; assuming main food item</td>
<td>0.700</td>
<td>Calculated; assuming main food item</td>
<td>0.700</td>
</tr>
<tr>
<td>Feed Ingestion Rate - Total</td>
<td>kg/day dry matter (dw)</td>
<td>13.5</td>
<td>Lyons et al., 1999; 2.5 % of bodyweight. See footnote 3.</td>
<td>11.4</td>
<td>Lyons et al., 1999; 2.5 % of bodyweight. See footnote 3.</td>
<td>1.25</td>
<td>Lyons et al., 1999; 2.5 % of bodyweight. See footnote 3.</td>
<td>1.98</td>
<td>Lyons et al., 1999 - 3.5 % of bodyweight. See footnote 3.</td>
<td>1.18</td>
<td>Lyons et al., 1999. 4 % of bodyweight. See footnote 3.</td>
<td>6.07</td>
</tr>
<tr>
<td>kg/kg body weight (bw)</td>
<td>0.0250</td>
<td>Calculated</td>
<td>0.0130</td>
<td>Calculated</td>
<td>0.0400</td>
<td>Calculated</td>
<td>0.0101</td>
<td>Calculated</td>
<td>0.0120</td>
<td>Calculated</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Soil Ingestion Rate (%agi)</td>
<td>Soil (bw)</td>
<td>2.42</td>
<td>Calculated. See footnote 4</td>
<td>2.13</td>
<td>Calculated. See footnote 4</td>
<td>0.235</td>
<td>Calculated. See footnote 4</td>
<td>0.955</td>
<td>Calculated. See footnote 4</td>
<td>0.354</td>
<td>Calculated. See footnote 4</td>
<td>1.82</td>
</tr>
<tr>
<td>Water Ingestion Rate (L/day)</td>
<td>Summer estimate</td>
<td>95.0</td>
<td>Agriculture Canada, 2002; Summer estimate of water ingestion for finishing cattle. See footnote 5.</td>
<td>86.0</td>
<td>Agriculture Canada, 2002; Summer estimate of water ingestion for finishing cattle. See footnote 5.</td>
<td>36.0</td>
<td>Agriculture Canada, 2002; Summer estimate of water ingestion for calves. See footnote 5.</td>
<td>14.0</td>
<td>Agriculture Canada, 2002; Summer estimate of water ingestion for calves. See footnote 5.</td>
<td>10.0</td>
<td>OAE, 1994; maximum of range.</td>
<td>16.5</td>
</tr>
<tr>
<td>Winter estimate</td>
<td>7.0</td>
<td>Agriculture Canada, 2002; estimates for milking cows. See footnote 5.</td>
<td>55.0</td>
<td>Agriculture Canada, 2002; estimates for finishing cattle. See footnote 5.</td>
<td>25.0</td>
<td>Agriculture Canada, 2002; estimates for calves. See footnote 5.</td>
<td>7.00</td>
<td>Agriculture Canada, 2002; estimates for calves.</td>
<td>7.00</td>
<td>OAE, 1999; minimum of range.</td>
<td>NA</td>
<td>—</td>
</tr>
<tr>
<td>Site Use Factor (SUFP)</td>
<td>1.00</td>
<td>Conservative assumption</td>
<td>1.00</td>
<td>Conservative assumption</td>
<td>1.00</td>
<td>Conservative assumption</td>
<td>1.00</td>
<td>Conservative assumption</td>
<td>1.00</td>
<td>Conservative assumption</td>
<td>1.00</td>
<td>Conservative assumption</td>
</tr>
</tbody>
</table>

Notes:

1. Body weights for cattle vary depending on region, breed, age, and lactation period.
2. Dairy cattle: 400 - 680 kg (BRBC, 2001); 408 kg - noted as a minimum (Ng et al., 1982).
3. Beef cattle: 230 kg (Bar et al., 1993); 250-440 kg (Skam et al., 1995); 454 kg (Lyons et al., 1999); 542 kg (SRC 2000; 1980 slaughter weight)
4. Cattle: 250 kg (Hedary et al., 2001); 50-80 kg (Hedary and Bouraha, 1996); 25 - 75 kg small breeds; 45 - 75 kg large breeds (SRC 2000)
5. Sheep: 17.6 kg for ewes (Florti et al., 2003).
6. Goats: 12.5 - 15.3 kg (Boss et al., 2001); and 11.7-16.9 kg (Boss et al., 1999, Angora goats).
7. Camels: are known to drink large quantities of water and to drink large quantities of seawater. A camel can drink up to 100 L/day in one time.
8. Other sources of soil ingestion rate for cattle: 0.1 - 1.2 kg/day with a high of 2.2 kg/day (Zach and Mayoh 1984); 0.72 - 2.5 L/day (Skam et al., 1995); 0.1 - 1.5 kg/day (Mayoh and Nguyen 1990); 0.4 kg/day (McKee and Kingsley 1989). 
9. Cattle: would use to expect to ingest large quantities of sand as they obtain their food from desert terrain.
### Table 2. Toxicity Studies for Mammals Exposed to Petroleum Hydrocarbons

<table>
<thead>
<tr>
<th>Animal</th>
<th>Compound</th>
<th>Route</th>
<th>Final Dose</th>
<th>Duration</th>
<th>Effect</th>
<th>Endpoint</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Calf</td>
<td>sweet crude oil</td>
<td>oral</td>
<td>8.0 ml/kg-bw/day</td>
<td>7-14 days</td>
<td>Mortality</td>
<td>LD80</td>
<td>Rowe 1972 and 1973 in Coppock et al. 1995</td>
</tr>
<tr>
<td>Calf</td>
<td>sweet crude oil</td>
<td>oral</td>
<td>37 ml/kg-bw/day</td>
<td>immediate</td>
<td>Mortality</td>
<td>LD100</td>
<td>Rowe 1972 and 1973 in Coppock et al. 1995</td>
</tr>
<tr>
<td>Calf</td>
<td>sour crude oil</td>
<td>oral</td>
<td>8.0 ml/kg-bw/day</td>
<td>16-23 days</td>
<td>Mortality</td>
<td>LD100</td>
<td>Rowe 1972 and 1973 in Coppock et al. 1995</td>
</tr>
<tr>
<td>Calf</td>
<td>kerosene</td>
<td>oral</td>
<td>8.0 ml/kg-bw/day</td>
<td>9-23 days</td>
<td>Mortality</td>
<td>LD100</td>
<td>Coppock et al. 1995</td>
</tr>
<tr>
<td>Cow</td>
<td>weathered oil</td>
<td>oral</td>
<td>7.3 g/kg-bw</td>
<td>26 days</td>
<td>Liver, GI, hematological, neurological effects</td>
<td>LOAEL</td>
<td>Stober 1962 in Coppock et al. 1995</td>
</tr>
<tr>
<td>Cow</td>
<td>unweathered oil</td>
<td>oral</td>
<td>2.5 ml/kg-bw/day</td>
<td>127 days</td>
<td>Liver, GI, hematological, neurological effects</td>
<td>LOAEL</td>
<td>Stober 1962 in Coppock et al. 1995 converted to a dose using Equation 3 in text.</td>
</tr>
<tr>
<td>Cow</td>
<td>unweathered oil</td>
<td>oral</td>
<td>2.1-4.2 g/kg-bw</td>
<td>26 days</td>
<td>Liver, GI, hematological, neurological effects</td>
<td>LOAEL</td>
<td>Stober 1962 in Coppock et al. 1995</td>
</tr>
<tr>
<td>Cow</td>
<td>Venezuelan crude</td>
<td>oral</td>
<td>4.0 mg/kg-bw</td>
<td>26 days</td>
<td>Liver, GI, hematological, neurological effects</td>
<td>LOAEL</td>
<td>Stober 1962 in Coppock et al. 1995</td>
</tr>
<tr>
<td>Cow</td>
<td>bunker “C” oil</td>
<td>oral</td>
<td>&gt;1.1 g/kg-bw/day</td>
<td>26 days</td>
<td>Liver, GI, hematological, neurological effects</td>
<td>LOAEL</td>
<td>Stober 1962 in Coppock et al. 1995</td>
</tr>
<tr>
<td>Rat</td>
<td>benzene</td>
<td>oral</td>
<td>357 mg/kg-bw/day</td>
<td>84 weeks</td>
<td>Hematological effects and decreased body weight.</td>
<td>LOAEL</td>
<td>Maltoni et al. 1983 in Stickney et al. 2001</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>35.7 mg/kg-bw/day</td>
<td>84 weeks</td>
<td></td>
<td>NOAEL</td>
<td>Extrapolated from LOAEL using UF of 10</td>
</tr>
<tr>
<td>Mouse</td>
<td>benzene</td>
<td>oral</td>
<td>263.6 mg/kg-bw/day</td>
<td>6-12 days of gestation period</td>
<td>Based on growth and development effects.</td>
<td>LOAEL</td>
<td>Nawrot and Stapels 1979 in Sample et al. 1996</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>26.36 mg/kg-bw/day</td>
<td></td>
<td></td>
<td>NOAEL</td>
<td>Extrapolated from LOAEL using UF of 10</td>
</tr>
<tr>
<td>Mouse</td>
<td>benzene</td>
<td>oral</td>
<td>8 mg/kg-bw/day</td>
<td>28 days</td>
<td>Based on hematological effects.</td>
<td>LOAEL</td>
<td>Hsieth et al. 1988 in Alberta Environment 2001</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>0.8 mg/kg-bw/day</td>
<td></td>
<td></td>
<td>NOAEL</td>
<td>Alberta 2001; extrapolated from LOAEL using UF of 10</td>
</tr>
<tr>
<td>Rat</td>
<td>toluene</td>
<td>oral</td>
<td>223 mg/kg-bw/day</td>
<td>13 weeks</td>
<td>Based on hepatic/renal effects.</td>
<td>NOAEL</td>
<td>NTP 1989 in IRIS/EPA 2003</td>
</tr>
<tr>
<td>Mouse</td>
<td>toluene</td>
<td>oral</td>
<td>260 mg/kg-bw/day</td>
<td>6-12 days of gestation period</td>
<td>Based on growth and development effects.</td>
<td>LOAEL</td>
<td>Nawrot and Stapels 1979 in Sample et al. 1996</td>
</tr>
<tr>
<td>Rat</td>
<td>toluene</td>
<td>oral</td>
<td>446 mg/kg-bw/day</td>
<td>13 weeks</td>
<td>Based on hepatic/renal effects.</td>
<td>NOAEL</td>
<td>NTP 1989 in Alberta Environment 2001</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>44.6 mg/kg-bw/day</td>
<td>5 days a weeks</td>
<td></td>
<td>NOAEL</td>
<td>Alberta 2001; extrapolated from LOAEL using UF of 10</td>
</tr>
<tr>
<td>Rat</td>
<td>ethylbenzene</td>
<td>oral</td>
<td>291 mg/kg-bw/day</td>
<td>182 days</td>
<td>Based on hepatic/renal effects.</td>
<td>LOAEL</td>
<td>Wolf et al., 1956 in IRIS/EPA 2003</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>29.1 mg/kg-bw/day</td>
<td></td>
<td></td>
<td>NOAEL</td>
<td>Extrapolated from LOAEL using UF of 10</td>
</tr>
</tbody>
</table>
Table 2. Toxicity Studies for Mammals Exposed to Petroleum Hydrocarbons (continued)

<table>
<thead>
<tr>
<th>Animal</th>
<th>Compound</th>
<th>Route</th>
<th>Final Dose</th>
<th>Duration</th>
<th>Effect</th>
<th>Endpoint</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rat</td>
<td>xylene</td>
<td>oral</td>
<td>179 mg/kg-bw/day</td>
<td>103 weeks; 5 days/week</td>
<td>Based on growth and development effects.</td>
<td>NOAEL</td>
<td>NTP 1986 in IRIS/EPA 2003</td>
</tr>
<tr>
<td>Rat</td>
<td>xylene</td>
<td>oral</td>
<td>357 mg/kg-bw/day</td>
<td>103 weeks; 5 days/week</td>
<td>Based on growth and development effects.</td>
<td>NOAEL</td>
<td>NTP 1986 in Alberta Environment 2001</td>
</tr>
<tr>
<td>Rat</td>
<td>naphthalene</td>
<td>oral</td>
<td>50 mg/kg-bw/day</td>
<td>6-15 days of gestation period</td>
<td>Increased maternal lethargy and slow breathing</td>
<td>LOAEL</td>
<td>Navarro et al., 1991</td>
</tr>
<tr>
<td>Mouse</td>
<td>xylene</td>
<td>oral</td>
<td>2.1 mg/kg-bw/day</td>
<td>6-15 days of gestation period</td>
<td>Reduced body weights and reduced water consumption</td>
<td>NOAEL</td>
<td>Extrapolated from LOAEL using UF of 10</td>
</tr>
<tr>
<td>Mouse</td>
<td>benzo(a)pyrene</td>
<td>oral intubation</td>
<td>10 mg/kg-bw/day</td>
<td>6-15 days of gestation period</td>
<td>Reduced pregnancy rates decreased percentage of viable litter</td>
<td>NOAEL</td>
<td>Extrapolated from LOAEL using UF of 10</td>
</tr>
<tr>
<td>Mouse</td>
<td>benzo(a)pyrene</td>
<td>oral intubation</td>
<td>16.67 mg/kg-bw/day</td>
<td>single dose (studied for 8-10 months)</td>
<td>Gastrointestinal papilloma</td>
<td>NOAEL</td>
<td>Bock and King, 1981</td>
</tr>
<tr>
<td>Rat</td>
<td>dibenz(a,h)anthracene</td>
<td>injected</td>
<td>0.2 mg/kg-bw/day</td>
<td>15 days</td>
<td>Reduced growth rate and gastrointestinal effects</td>
<td>NOAEL</td>
<td>Haddow et al., 1937</td>
</tr>
</tbody>
</table>

Note: bolded studies were selected as appropriate to develop toxicity values for livestock.

IRIS = Integrated risk information system
LOAEL = Lowest observable adverse effects level.
NOAEL = No observable adverse effects level.
NTP = National Toxicology Program.

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>UF</td>
<td>Uncertainty factor.</td>
</tr>
<tr>
<td>g/kg-bw</td>
<td>Grams per kilogram body weight.</td>
</tr>
<tr>
<td>mg/kg-bw</td>
<td>Milligrams per kilogram body weight.</td>
</tr>
<tr>
<td>mg/kg-bw/day</td>
<td>Milligrams per kilogram body weight per day.</td>
</tr>
<tr>
<td>ml/kg-bw/day</td>
<td>Milliliters per kilogram body weight per day.</td>
</tr>
<tr>
<td>a</td>
<td>After adjustment dosing times.</td>
</tr>
</tbody>
</table>
4.2 Exposure Assumptions
The following sections describe the input parameters used in the dose model (Equation 1) above. Exposure assumptions used in the development of TRVs and RBSLs in this report are presented in Table 1.

4.2.1 Body Weight
Body weights are available in various literature sources. Cattle and other livestock can range in size depending on their production value (e.g., dairy or beef cattle) and age (e.g., calves, growing cattle, finishing cattle, mature cows or bulls), as well as their location (e.g., livestock from third world countries tend to be smaller). In this approach, parameters have been provided for three subsets of the cattle receptor: dairy cattle, beef cattle, and calves. The average cattle body weights were taken from the NRC reports on nutrient requirements for dairy cattle and calves (NRC 2001, 2000).

- Dairy Cattle – Ng et al. (1982) cited a 1979 value of 480 kg for dairy cows, noting that individual cows from dairy herds were larger than their proposed value, as mature weights of dairy cattle vary from 400 kg for small breeds to over 680 kg for large breeds (NRC 2001). However, an average value of 540 kg was used in this report.

- Beef Cattle – The Texas Agricultural Extension Service (Lyons et al. 1999) cited an estimated average live weight of 454 kg (1,000 lbs) for beef cattle. Other literature values included 230 kg (Stair et al. 1995) and 250 kg to 460 kg (Khan et al. 1995). The NRC (2000) indicated that the current population of beef cattle in the United States varied considerably in biological type, and slaughter weight ranged from 399 kg to 644 kg. The average steer slaughter weight in 1991 was 542 kg (NRC 2000). The Texas value of 454 kg was used in this report as it fell within the range of all the available values.

- Calves – The average calf body weight used in this report was also from NRC (2000). The range presented was 25 kg to 75 kg for small and large breeds. Other values in the literature were 236 kg (Stickney et al. 2001) and 50 kg to 60 kg (Upadhyay and Swarup 1994). The midpoint of the range weights in the NRC (2000), 50 kg, was used for calf body weight.

Sheep and goat body weights were from the values cited by the Texas Agricultural Extension Service (Lyons et al. 1999) for sheep (56.7 kg) and Spanish goats (29.5 kg). The sheep body weight used was slightly larger than the only other value identified for sheep, 37.6 kg for ewes (Floris et al. 2000). Other values for goats identified in the literature were 12.5 to 13.5 kg (Bose et al. 2001) and 31.7 kg (Lyons et al. 1999; Angora goats).

Exposures to camels were evaluated to address potential risks to livestock outside of the United States. Body weights can vary depending on the camel type (i.e., dromedary, bactrian, or llamas). An average body weight of 600 kg was used in this report (based on various internet sources; e.g., http://www.arab.net/camels/ and http://www.oaklandzoo.org/atoz/azarabcamel.html and a study by Gihad et al. 1989).

Horse body weights can also vary depending on the breed. Environment Canada (1999) cited body weights between 500 kgs and 600 kgs. The mid-point range of 550 kgs was used in this report (Table 1). Other studies have indicated that horse body weights can be estimated in kgs with a simple formula (Ontario Ministry of Agriculture and Food [OMAFRA] 1999a) using heartgirth circumference, body length, and an adjustment factor. Horse body weight used in this report were within the range of body weights reported in OMAFRA (1999a) and calculated using the formula (i.e., 45.5 kgs to 591 kgs).
4.2.2 Dietary Composition
For screening-level risk assessment purposes, livestock was assumed to obtain all nutrients from forage material. As some receptors, beef cattle in particular, may consume store-bought feed in substantial dietary proportions, this component of the daily dose model (Equation 1) may result in overestimates of risk and may be an area of refinement in secondary tiers of analysis.

4.2.3 Food Ingestion Rate
Conservative food ingestion rates for beef cattle, sheep, and Spanish goats were derived using intake factors from the Texas Agricultural Extension Service (Lyons et al. 1999). The daily food intakes as dry matter (i.e., dry weight) for grazers like dairy cattle, beef cattle, and calves, were estimated as 2.5% of their body weight; and for intermediate feeders like sheep and goats, were estimated at 3.5% and 4% of body weights, respectively. The food ingestion rates calculated in dry weight were 13.5, 11.4, 1.25, 1.98, 1.18 kg/day for dairy cattle, beef cattle, calves, sheep, and goats, respectively (Table 1). These values were comparable to other values found in the literature sources. Ng et al. (1982) cited values of 10, 10, and 1.6 kg/day dry matter for dairy cattle, beef cattle, and sheep respectively. The International Atomic Energy Agency (IAEA 1994) cited expected (mean) values of 16.1, 7.2, 1.9, 1.3, and 1.3 kg/day for dairy cows, beef cattle, calves, dairy sheep, and dairy goats, respectively.

For camels fed whole hay, a food ingestion rate of 6.07 kg/day dry matter reported by Gihad et al. (1989) was used in this report.

Horses generally consume 2.5% of their body weight in dry matter daily (OMAFRA 1999b). The food ingestion rate for horses calculated in dry weight was 13.8 kg/day. Other food ingestion rates reported in literature included 13 kg/day to 25 kg/day (Environment Canada 1999). Note that although horses and cows are grazers, horses can consume up to 70% more forage than cows of similar body size because of the difference in their digestion process (Lyons et al., 1999).

4.2.4 Incidental Soil Ingestion Rate (IRsoil)
Soil ingestion rates (IRsoil) were derived by multiplying the literature values of percentage soil found in the diet by the total daily food ingestion rate. Percentages of soil in the diet of dairy cattle, beef cattle, calves, sheep, and goats were from Thornton and Abrahams (1983) and Abrahams and Thornton (1994). An extensive review of the literature sources produced values for cattle soil ingestion that included 2% to 14% (Healy 1968) and 4% to 14% (Fries et al. 1982) for dairy cattle; 1.2% to 18.8% for range cattle (Zach and Mayoh 1984); 0.2% to 17.9% (Thornton and Abrahams 1983) for range or beef cattle; maximum recorded value of 17.9% in agricultural cattle (Abrahams and Thornton 1994), and 18.8% for calves and beef cattle (Kennedy and Strenge 1992). The maximum soil dietary percentage of 17.9% (Thornton and Abrahams 1983; Abrahams and Thornton 1994) was used for the generation of conservative threshold values: for dairy cattle and 18.8% (Kennedy and Strenge 1992) was used for calves and beef cattle. The soil dietary percentages resulted in the following values for incidental soil ingestion rates (in dry weight): 2.42 kg/day for dairy cattle, 2.13 kg/day for beef cattle, and 0.235 kg/day for calves. Literature values for incidental soil ingestion rates for cattle were similar and included 0.5 kg/day to 1.2 kg/day with a high of 2.2 kg/day (Zach and Mayoh 1984), 0.72 kg/day to 2.56 kg/day (Fries et al., 1982), 0.1 kg/day to 1.5 kg/day (Mayland et al. 1977), 0.1 kg/day to 0.72 kg/day (McKone and Ryan 1989), and 0.4 kg/day (McKone 1994).

The only soil intake value identified in the literature for sheep was an upper-end estimate of 30% of dietary intake (Thornton and Abrahams 1983) that resulted in an incidental soil ingestion rate of 0.595 kg/day. Values were unavailable for goats, therefore, the percent soil intake was extrapolated to goats,
assuming similar food consumption rates and grazing behavior which resulted in an incidental soil ingestion rate (in dry weight) of 0.354 kg/day.

Soil ingestion rates for camels could not be found. Camels tend to eat plants and other items found in the desert terrain. As a result, it can be assumed that camels may consume significant quantities of sand/soil. To be conservative, the percent of soil ingested by camels was assumed to be the maximum percent soil ingested of all the livestock receptors (i.e., sheep). Therefore, a calculated soil ingestion rate (in dry weight) of 1.82 kg/day for camels was used in this report.

Soil ingestion rates could not be found for horses. As explained earlier, horses tend to digest food rapidly. Horses may consume more food than cows of similar size and, subsequently, may consume more soil. Therefore, conservatively, the percent of soil ingested by horses was assumed to be the maximum percent soil ingested of all the livestock receptors (i.e. sheep; Table 1). The calculated soil ingestion rate (in dry weight) of 4.13 kg/day for horses was used in this report.

4.2.5 Water Ingestion Rate (IRwater)

Water ingestion rates for dairy cattle, beef cattle, calves, and sheep were taken from estimates provided by Agriculture and Agri-food Canada (2002). Values varied seasonally, and for this reason, summer and winter estimates are provided. These values (summer/winter) were as follows: 95/77 L/day for dairy cattle; 86/55 L/day for beef cattle (finishing cattle); 36/23 L/day for calves; and 14/3.6 L/day for sheep. For goats, the daily water intake was 10/5 L/day from IAEA (1994). Additional ranges presented in the literature included 50 L/day to 100 L/day for dairy cattle, 20 L/day to 60 L/day for beef cattle, 5 L/day to 15 L/day for calves, 5 L/day to 8 L/day for sheep (IAEA 1994), 56.8 L/day for cattle (Fairies et al. 1998), and up to 100 L/day for cattle (CCME 2000).

For camels, one study (Gihad et al. 1989) on the daily water ingestion rates reported 16.5 L/day which was used in this report (no specific summer and winter drinking water intakes were available). Note that camels can go for days without drinking water (maximum of 1 month) and can drink large volumes of water at one time.

Daily water intake for horses were reported in Environment Canada (1999) and ranged from 15 L/day to 42 L/day. As no specific summer and winter water intake rates were available for horses, the lower limit of the range (i.e., 15 L/day) was used as the winter water ingestion rate and the upper end of the range (i.e., 42 L/day) was used as the summer water ingestion rate.

4.2.6 Site Use Factor (SUF)

The SUF represents the fraction of the exposure area for the receptor represented by the contamination area and is a unitless factor generally calculated by dividing the contamination area by the home or foraging range of the receptor. Because any evaluation of risk to livestock would be focused on protecting a particular population or herd, the effective grazing area of the herd in question would substitute for the home range and this value would be site specific. The RBSLs presented herein were calculated assuming a default SUF of 1 (i.e., the contamination area is as large as the effective grazing area) for exposure via each of the significant exposure pathways (i.e., SUF for exposure via drinking water ingestion and SUF via incidental soil ingestion). As mentioned earlier, the size of the contaminated area is an important factor in determining the overall need to conduct a risk assessment.
4.3 Effects Assessment

The assessment endpoints used in developing TRVs were based on survival, reproductive, development and growth endpoints of the herd community. The measurement endpoints used to quantify the assessment endpoints were preferably based on chronic no-observable adverse effect levels (NOAELs). For unavailable or unreported NOAELs, the lowest-observable adverse effects levels (LOAELs) were extrapolated to develop NOAELs using an uncertainty factor of 10 following EPA guidelines (EPA 1999):

\[
\text{chronicNOAEL} = \frac{\text{chronicLOAEL}}{UF}
\]

Where:
- \( \text{chronicLOAEL} \) = chronic lowest observable adverse effects level in milligrams per kilogram body weight per day (mg/kg-bw/day)
- \( \text{chronicNOAEL} \) = chronic no-observable adverse effects level in milligrams per kilogram body weight per day (mg/kg-bw/day)
- \( UF \) = uncertainty factor = 10; unitless

Two of the complete and potentially significant exposure pathways identified in the CSM (Figure 1) for livestock included incidental soil ingestion and drinking water ingestion. Minor exposure pathways included dermal contact and inhalation, which do not contribute significantly to overall exposure. Therefore, drinking water and soil RBSLs were developed for the protection of livestock from exposure to petroleum hydrocarbons, including crude oil, BTEX, and PAHs based on the exposure assumptions described above and presented in Table 1, and using TRVs which are discussed below.

4.4 Crude Oil

TRVs and RBSLs developed for livestock receptors exposed to whole crude oil are described below and presented in Table 3.

4.4.1 Development of Crude Oil TRVs for Livestock

Toxicity studies available for crude oil effects on livestock are summarized in Table 2. Most of the toxicity endpoints in the studies listed in Table 2 were based on lethal endpoints. However, a study conducted by Stober in 1962 evaluated sublethal toxicity endpoints and therefore, was selected to develop TRVs for this report. The toxicity endpoints in Stober’s study were based on chronic LOAELs for fresh and weathered crude oil in cattle, particularly on altered rumen function, loss of appetite, decreased liver function, increased eosinophil (i.e. a type of white blood cell) number, hypomagnesemia (which can lead to heart and kidney problems), apathy, and emaciation.

The crude oil TRV for the protection of livestock was based on a toxicity test performed on a 4-month-old cow administered fresh (i.e., unweathered) crude oil in its diet for a 127-day treatment period (Stober 1962). The chronic LOAEL was reported as 2.5 ml/kg-bw/day (Stober 1962 as cited in Coppock et al. 1995) which was converted into a dose expression using the specific gravity value reported (Stober 1962) as follows:

\[
\text{chronicLOAEL}(\text{ml/kg – bw/day}) \times \text{sg(g/ml)} \times 1000 = \text{chronicLOAEL}(\text{mg/kg – bw/day})
\]

Equation 3
Based on Equation 3, the chronic LOAEL for fresh crude oil (unweathered) was 2,108 mg/kg-bw/day, which was extrapolated to a chronic NOAEL using Equation 2 resulting in a TRV of 211 mg/kg-bw/day. As shown in Table 3, this TRV of 211 mg/kg-bw/day for whole fresh crude oil was used to develop RBSLs for all types of livestock.

In recent studies, subchronic effects of crude oil on cattle (Dziwenka et al, 2002) and sheep (Coppock et al. 2002) were reported. In these studies, cattle and sheep were orally administered crude oil at doses that were similar or higher than those listed in Table 2. It can be assumed that toxicity values developed, based on these recent studies, would be similar or less conservative than the values developed in this report (i.e., based on Stober’s [1962] study). Therefore, crude oil TRV for livestock based on Stober’s study (1962) is used in this report.
<table>
<thead>
<tr>
<th>Receptor</th>
<th>BW (kg)</th>
<th>TRV (mg/kg bw/day)</th>
<th>IR_{summer} (L/day)</th>
<th>dw-RBSL (mg/L)</th>
<th>IR_{soil} (kg/day)</th>
<th>soil-RBSL (mg/kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dairy Cattle</td>
<td>540</td>
<td>211</td>
<td>95.0</td>
<td>1,199</td>
<td>2.42</td>
<td>47,151</td>
</tr>
<tr>
<td>Beef Cattle</td>
<td>454</td>
<td>211</td>
<td>86.0</td>
<td>1,114</td>
<td>2.13</td>
<td>44,894</td>
</tr>
<tr>
<td>Calves</td>
<td>50.0</td>
<td>211</td>
<td>36.0</td>
<td>293</td>
<td>0.235</td>
<td>44,894</td>
</tr>
<tr>
<td>Sheep</td>
<td>56.7</td>
<td>211</td>
<td>14.0</td>
<td>855</td>
<td>0.595</td>
<td>20,095</td>
</tr>
<tr>
<td>Goat</td>
<td>29.5</td>
<td>211</td>
<td>10.0</td>
<td>622</td>
<td>0.354</td>
<td>17,583</td>
</tr>
<tr>
<td>Camel</td>
<td>600</td>
<td>211</td>
<td>16.5</td>
<td>7,673</td>
<td>1.82</td>
<td>69,522</td>
</tr>
<tr>
<td>Horses</td>
<td>550</td>
<td>211</td>
<td>42.0</td>
<td>2,763</td>
<td>4.13</td>
<td>28,133</td>
</tr>
</tbody>
</table>

Note:

- dw-RBSL = \(\frac{(TRV \times BW)}{IR_{summer}}\)
- soil-RBSL = \(\frac{(TRV \times BW)}{IR_{soil}}\)

Where:
- dw-RBSL: Drinking water risk-based screening level.
- soil-RBSL: Soil risk-based screening level.
- TRV: Toxicity reference value.
- BW: Body weight; from Table 1.
- IR_{summer}: Water ingestion rate during summer; from Table 1.
- IR_{soil}: Soil ingestion rate; from Table 1.
- kg: Kilograms.
- L/day: Liters per day.
- mg/L: Milligrams per liter.
- mg/kg: Milligrams per kilogram.
- mg/kg bw/day: Milligrams per kilogram body weight per day.
4.4.2 Development of Crude Oil Drinking Water RBSLs and Soil RBSLs for Livestock

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).

\[
HQ = \frac{Dose}{TRV}
\]

Equation 4a

Substituting Equation 1 for “Dose” in Equation 4a:

\[
HQ = \left[ (IR_{soil} \times C_{soil}) + (IR_{water} \times C_{water}) \right] \times SUF
\]

\[
= \frac{BW \times TRV}{BW \times TRV}
\]

Equation 4b

or

\[
HQ = \frac{(IR \times C) \times SUF}{BW \times TRV}
\]

Equation 4c

To calculate RBSLs for a single media (i.e., drinking water or soil), Equation 4c was rearranged as shown in Equations 5a and 5b. Instead of estimating a HQ associated with a chemical concentration in water or soil using the toxicity and exposure assumptions presented in Table 1, Equations 5a and 5b estimated a protective drinking water or soil concentration associated with a target HQ of 1.

Assuming target HQ = 1; SUF = 1; and rearranging Equation 4c, “C” becomes defined as the corresponding RBSL.

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

\[
d_{waterRBSL} = \frac{1 \times BW \times TRV}{IR_{water}}
\]

Equation 5a

Where:

- 1 = target hazard quotient; unitless
- \(d_{waterRBSL}\) = 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:

\[
s_{soilRBSL} = \frac{1 \times BW \times TRV}{IR_{soil}}
\]

Equation 5b
Where:

- \( I = \) target hazard quotient; unitless
- \( soilRBSL = \) soil RBSL in milligrams per kilogram dry weight (mg/kg)
- \( IRsoil = \) 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)

Based on the equations above and the TRV developed for whole fresh crude oil, drinking water RBSLs and soil RBSLs were calculated for a variety of livestock receptors and presented in Table 3. Drinking water RBSLs ranged from 293 mg/L (calves) to 7,673 mg/L (camels) and soil RBSLs ranged from 17,583 mg/kg (goats) to 69,522 mg/kg (camels).

In a screening-level risk assessment for a site, these RBSLs can be directly compared to crude oil concentrations, generally expressed as total petroleum hydrocarbon (TPH), at that site. Because the TRV for crude oil was developed based on whole fresh or unweathered crude oil, and weathered crude oil is generally less toxic (United States Fish and Wildlife Service [USFWS] 1998), TRVs and RBSLs for unweathered crude oil can be used for evaluating fresh spills and can be considered a conservative screening value for weathered spills.

### 4.5 Benzene, Toluene, Ethylbenzene, and Xylene (BTEX)

TRVs and RBSLs developed for livestock receptors exposed to BTEX are described below and presented in Tables 4 and 5.

#### 4.5.1 Development of BTEX TRVs for Livestock

BTEX toxicity values were unavailable in literature for livestock. However, BTEX toxicity values were available for small mammals and are presented in Table 2. BTEX TRVs for livestock were developed based on small mammal toxicity studies and extrapolated to a dose that would be protective of livestock. In this report, where available, toxicity studies reported in EPA’s Integrated Risk Information System (EPA/IRIS 2003) were used to develop TRVs for BTEX.

**Benzene:** The TRV for benzene was based on a toxicity study conducted by Maltoni *et al.* in 1983 (as cited in Stickney *et al.* 2001) where rats were administered oral doses of benzene 5 times a week for 84 weeks. The chronic LOAEL reported was 500 mg/kg-bw/day (NOAEL was not available) based on hematological effects and changes in body weight in the rats. The chronic LOAEL was adjusted for the dosing schedule (i.e., 5 days a week), which resulted in a value of 357 mg/kg-bw/day. To develop benzene TRVs for this report, the chronic LOAEL reported above was extrapolated to a chronic NOAEL using Equation 2 and resulted in a value of 35.7 mg/kg-bw/day. A significant difference in body weight between the test-species (e.g., rat weighing 0.35 kg; from Sample *et al.* 1996) and livestock requiring a scaling factor to allometrically adjust for the difference in body weights (Sample 1996; EFA 1998) following Equation 6 below (Sample and Arenal 1999). The calculated benzene TRVs for livestock based on chronic NOAELs are presented in Table 4 and range from 5.55 mg/kg-bw/day (camels) to 11.8 mg/kg-bw/day (goats).
Where:

\[ SF = \left( \frac{BW_{test\ species}}{BW_{livestock}} \right)^{1/4} \]  

\[ SF \] = scaling factor (unitless)

\[ BW_{test\ species} \] = body weight of test species in kilograms (kg)

\[ BW_{livestock} \] = body weight of livestock receptor in kilograms (kg)

**Toluene:** The TRV for toluene was based on a toxicity study conducted by the National Toxicology Program (NTP) in 1989 (as cited in EPA/IRIS 2003). Rats were administered oral doses of toluene 5 times a week for 13 weeks. The chronic NOAEL reported was 312 mg/kg-bw/day based on liver and kidney changes in male rats, and was further adjusted for the dosing schedule. This resulted in a value reported as 223 mg/kg-bw/day (a LOAEL of 625 mg/kg-bw/day was also reported in this study). To develop toluene TRVs for this report, the chronic NOAEL reported above was adjusted for differences in body weight between rats and livestock using Equation 6. The calculated toluene TRVs for livestock are shown in Table 4 and range from 34.6 mg/kg-bw/day (camels) to 73.6 mg/kg-bw/day (goats).

**Ethylbenzene:** The TRV for ethylbenzene was based on a toxicity study conducted by Wolf et al. in 1956 (as cited in EPA/IRIS 2003). Rats were administered oral doses of ethylbenzene 5 days a week for 182 days. The chronic LOAEL reported was 408 mg/kg-bw/day (NOAEL was not available) based on histopathologic changes in liver and kidney in rats and was further adjusted for the dosing schedule, resulting in a value reported as 291 mg/kg-bw/day. To develop ethylbenzene TRVs for this report, the chronic LOAEL reported above was extrapolated to a chronic NOAEL using Equation 2 resulting in a value of 29.1 mg/kg-bw/day which was further adjusted for differences in body weight between rats and livestock using Equation 6. The calculated ethylbenzene TRVs for livestock are presented in Table 4 and range from 4.53 mg/kg-bw/day (camels) to 9.62 mg/kg-bw/day (goats).

**Xylene:** The TRV for xylene was based on a toxicity study conducted by NTP in 1986 (as cited in EPA/IRIS 2003). Rats were administered oral doses of xylene 5 times a week for 103 weeks. The chronic NOAEL reported was 250 mg/kg-bw/day (a LOAEL of 500 mg/kg-bw/day was also reported in this study) based on decreased body weight and decreased survival and was further adjusted for the dosing schedule resulting in a value reported as 179 mg/kg-bw/day. To develop xylene TRVs for this report, the chronic NOAEL reported above was further adjusted for differences in body weight between rats and livestock using Equation 6. The calculated xylene TRVs for livestock are presented in Table 4 and range from 27.8 mg/kg-bw/day (camels) to 58.9 mg/kg-bw/day (goats).
Table 4. Benzene, Toluene, Ethylbenzene, and Xylene (BTEX) TRVs for Livestock

<table>
<thead>
<tr>
<th>Chemical</th>
<th>Endpoint (mg/kg-bw/day)</th>
<th>Adjustments (unitless)</th>
<th>Adjusted Endpoint (mg/kg-bw/day)</th>
<th>NOAEL (mg/kg-bw/day)</th>
<th>BW&lt;sub&gt;test species&lt;/sub&gt; (kg)</th>
<th>Study</th>
<th>Receptor: BW&lt;sub&gt;livestock&lt;/sub&gt; (kg): SF (unitless)</th>
<th>Livestock TRVs (mg/kg-bw/day)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Benzene</td>
<td>500 LOAEL</td>
<td>0.714</td>
<td>357</td>
<td>35.7</td>
<td>0.350</td>
<td></td>
<td>5.70</td>
<td>5.95 10.3 10.0 11.8 5.55 5.67</td>
</tr>
<tr>
<td></td>
<td>NA NOAEL</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Toluene</td>
<td>625 LOAEL</td>
<td>0.714</td>
<td>223</td>
<td>223</td>
<td>0.350</td>
<td></td>
<td>35.6</td>
<td>37.1 64.5 62.5 73.6 34.6 35.4</td>
</tr>
<tr>
<td></td>
<td>312 NOAEL</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ethylbenzene</td>
<td>408 LOAEL</td>
<td>0.714</td>
<td>291</td>
<td>29.1</td>
<td>0.350</td>
<td></td>
<td>4.65</td>
<td>4.86 8.43 8.17 9.62 4.53 4.63</td>
</tr>
<tr>
<td></td>
<td>NA NOAEL</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Xylene</td>
<td>500 LOAEL</td>
<td>0.714</td>
<td>179</td>
<td>179</td>
<td>0.350</td>
<td></td>
<td>28.5</td>
<td>29.8 51.7 50.1 58.9 27.8 28.4</td>
</tr>
<tr>
<td></td>
<td>250 NOAEL</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Note:
TRV for Livestock = NOAEL * SF

Where:
- TRV: Toxicity reference value
- NOAEL: No observable adverse effect level
- SF: Scaling factor; from Sample and Arenal 1999 = (BW<sub>test species</sub>/BW<sub>livestock</sub>)<sup>a</sup>
- BW<sub>test species</sub>: Body weight for test species (i.e. rat); from Sample et al., 1996.
- BW<sub>livestock</sub>: Body weight for livestock; from Table 1.
- kg: Kilograms.
- mg/kg-bw/day: Milligrams per kilogram body weight per day.
- BTEX: Benzene, Toluene, Ethylbenzene, and Xylene.
- LOAEL: Lowest observable adverse effect level.
- NA: Not available.
- a Adjusting for dosing schedule of 5 days per week (i.e. 5/7 = 0.71).
- b Maltoni et al. 1983 in Stickney et al. 2001; from Table 2.
- c e NTP 1986 in IRIS/EPA 2003; from Table 2.
- d Wolf et al., 1956 in IRIS/EPA 2003; from Table 2.
4.5.2 Development of BTEX Drinking Water RBSLs and Soil RBSLs for Livestock

BTEX RBSLs for the protection of livestock were developed using the same approach as described earlier for crude oil RBSLs (Section 3.4.1). BTEX drinking water RBSLs were developed using Equation 5a and BTEX soil RBSLs were developed using Equation 5b for livestock. The calculated RBSLs are presented in Table 5. Drinking water RBSLs ranged from 14.3 mg/L (calves) to 202 mg/L (camels) for benzene; from 89.5 mg/L (calves) to 1,259 mg/L (camels) for toluene; from 11.7 mg/L (calves) to 165 mg/L (camels) for ethylbenzene; and from 71.7 mg/L (calves) to 1,009 mg/L (camels) for xylene. Soil RBSLs ranged from 756 mg/kg (horses) to 2,198 mg/kg (calves) for benzene; from 4,719 mg/kg (horses) to 13,715 mg/kg (calves) for toluene; from 617 mg/kg (horses) to 1,794 mg/kg (calves) for ethylbenzene; and from 3,782 mg/kg (horses) to 10,990 mg/kg (calves) for xylene.

4.6 Polycyclic Aromatic Hydrocarbons (PAHs)

TRVs and RBSLs developed for livestock receptors exposed to PAHs are described below and presented in Tables 6 and 7.

4.6.1 Development of PAH TRVs for Livestock

Toxicity values were available for PAHs for livestock. However, PAH TRVs for small mammals were available and are shown in Table 6. Similar to BTEX, PAH TRVs for livestock were developed based on small mammal toxicity values (Table 2) extrapolated to a dose that would be protective of livestock. PAH toxicity studies on small mammals were reviewed and appropriate studies were selected to develop TRVs for livestock. The limited availability of suitable data allowed for the selection of only two TRVs, one for low molecular weight (LMW) PAHs and one for high molecular weight (HMW) PAHs. LMW PAHs are defined as PAHs with less than or equal to 3 rings and with molecular weight less than or equal to 192 atomic mass units (amu) (National Oceanic and Atmospheric Administration [NOAA] 2000). Parent LMW PAHs include naphthalene, acenaphthylene, acenaphthene, fluorene, anthracene, and phenanthrene. HMW PAHs are defined as PAHs with greater than or equal to 4 rings and with molecular weight greater than or equal to 202 amu (NOAA 2000). Parent HMW PAHs include pyrene, fluoranthene, benzo(a)anthracene, chrysene, benzo(a)pyrene, perylene, benzo(e)pyrene, benzo(b) fluoranthene, benzo(j)fluoranthene, benzo(k)fluoranthene, benzo(g,h,i)perylene, indeno(1,2,3-cd)pyrene, and dibenz(a,h)anthracene.

The TRV for LMW PAHs was based on a toxicity study conducted by Navarro et al. in 1991. Rats were administered oral doses of naphthalene during 6 to 15 days of gestation. The chronic LOAEL was calculated as 50 mg/kg-bw/day based on increased maternal lethargy and slow breathing in rats. To develop LMW PAH TRVs for this report, the chronic LOAEL was extrapolated to a chronic NOAEL using Equation 2 which resulted in a value of 5 mg/kg-bw/day; this was further adjusted for differences in body weight between rats and livestock using Equation 6. The calculated LMW PAH TRVs for livestock are shown in Table 6 and range from 0.777 mg/kg-bw/day (camels) to 1.65 mg/kg-bw/day (goats). Of all the LMW PAHs, naphthalene is considered the most toxic to mammals. Therefore, risks estimated for livestock exposed to other LMW PAHs at a site using the LMW PAH TRV developed in this report would be considered conservative.
### Table 5. Benzene, Toluene, Ethylbenzene, and Xylene (BTEX) TRVs and RBSLs for Livestock

<table>
<thead>
<tr>
<th>Receptor</th>
<th>BW (kg)</th>
<th>TRV (mg/kg-bw/day)</th>
<th>IR&lt;sub&gt;water&lt;/sub&gt; (L/day)</th>
<th>dw-RBSL (mg/L)</th>
<th>IR&lt;sub&gt;soil&lt;/sub&gt; (kg/day)</th>
<th>Soil RBSL (mg/kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Benzene</td>
<td>Toluene</td>
<td>Ethylbenzene</td>
<td>Xylene</td>
<td>Benzene</td>
</tr>
<tr>
<td>Dairy Cattle</td>
<td>540</td>
<td>5.70</td>
<td>35.6</td>
<td>4.65</td>
<td>28.5</td>
<td>95.0</td>
</tr>
<tr>
<td>Beef Cattle</td>
<td>454</td>
<td>5.95</td>
<td>37.1</td>
<td>4.86</td>
<td>29.8</td>
<td>86.0</td>
</tr>
<tr>
<td>Calves</td>
<td>50.0</td>
<td>10.3</td>
<td>64.5</td>
<td>8.43</td>
<td>51.7</td>
<td>36.0</td>
</tr>
<tr>
<td>Sheep</td>
<td>56.7</td>
<td>10.0</td>
<td>62.5</td>
<td>8.17</td>
<td>50.1</td>
<td>14.0</td>
</tr>
<tr>
<td>Goat</td>
<td>29.5</td>
<td>11.8</td>
<td>73.6</td>
<td>9.62</td>
<td>58.9</td>
<td>10.0</td>
</tr>
<tr>
<td>Camel</td>
<td>600</td>
<td>5.55</td>
<td>34.6</td>
<td>4.53</td>
<td>27.8</td>
<td>16.5</td>
</tr>
<tr>
<td>Horse</td>
<td>550</td>
<td>5.67</td>
<td>35.4</td>
<td>4.63</td>
<td>28.4</td>
<td>42.0</td>
</tr>
</tbody>
</table>

Note:
- dw-RBSL = \( \frac{(TRV \times BW)}{IR_{water}} \)
- soil-RBSL = \( \frac{(TRV \times BW)}{IR_{soil}} \)

Where:
- dw-RBSL: Drinking water risk-based screening level.
- soil-RBSL: Soil risk-based screening level.
- TRV: Toxicity reference value.
- BW: Body weight; from Table 1.
- IR<sub>water</sub>: Water ingestion rate during summer; from Table 1.
- IR<sub>soil</sub>: Soil ingestion rate; from Table 1.
- kg: Kilograms.
- L/day: Liters per day.
- mg/L: Milligrams per liter.
- mg/kg: Milligrams per kilogram.
- mg/kg bw/day: Milligrams per kilogram body weight per day.
The TRV for HMW PAHs was based on a toxicity study conducted by MacKenzie and Angevine in 1981. Mice were administered oral doses of benzo(a)pyrene during 7 to 16 days of gestation. The chronic LOAEL was calculated as 10 mg/kg-bw/day based on reduced pregnancy rates and decreased percentage of viable mice liter. To develop HMW PAH TRVs for this report, the chronic LOAEL was extrapolated to a chronic NOAEL using Equation 2 and resulted in a value of 1 mg/kg-bw/day. This chronic NOAEL was further adjusted for differences in body weight between mice (0.03 kg; from Sample et al., 1996) and livestock using Equation 5. The calculated HMW PAH TRVs for livestock are presented in Table 6 and range from 0.155 mg/kg-bw/day (camels) to 0.330 mg/kg-bw/day (goats).

4.6.2 Development of PAH Drinking Water RBSLs and Soil RBSLs for Livestock

PAH RBSLs for the protection of livestock were developed using the same approach as crude oil RBSLs described earlier (Section 3.4.1). PAH drinking water RBSLs were developed using Equation 5a and PAH soil RBSLs were developed using Equation 5b for livestock. The calculated RBSLs are shown in Table 7. Drinking water RBSLs ranged from 2.01 mg/L (calves) to 28.3 mg/L (camels) for LMW PAHs and from 0.402 mg/L (calves) to 5.65 mg/L (camels) for HMW PAHs. Soil RBSLs ranged from 106 mg/kg (horses) to 308 mg/kg (calves) for LMW PAHs and from 21.2 mg/kg (horses) to 61.5 mg/kg (calves) for HMW PAHs.

As LMW PAH RBSLs were developed based on the LMW PAH TRV which was based on naphthalene (one of the most toxic of all the LMW PAHs to mammals), risks estimated for livestock exposed to other LMW PAHs at a site using the RBSLs developed in this report for LMW PAH would be considered conservative.
Table 6. Polycyclic Aromatic Hydrocarbon (PAH) TRVs for Livestock

<table>
<thead>
<tr>
<th>Chemical</th>
<th>Test Species</th>
<th>LOAEL (mg/kg-bw/day)</th>
<th>UF (unitless)</th>
<th>NOAEL (mg/kg-bw/day)</th>
<th>BW&lt;sub&gt;test species&lt;/sub&gt; (kg)</th>
<th>Study</th>
<th>Receptor: BW&lt;sub&gt;animals&lt;/sub&gt; (kg): SF (unitless):</th>
<th>Livestock TRVs (mg/kg-bw/day)</th>
</tr>
</thead>
<tbody>
<tr>
<td>LMW PAH</td>
<td></td>
<td>50</td>
<td>10</td>
<td>5</td>
<td>0.35</td>
<td></td>
<td>0.16</td>
<td>0.798, 0.833, 1.45, 1.40, 1.65, 0.777, 0.794</td>
</tr>
<tr>
<td>HMW PAH</td>
<td></td>
<td>10</td>
<td>10</td>
<td>1</td>
<td>0.03</td>
<td></td>
<td>0.16</td>
<td>0.160, 0.167, 0.289, 0.280, 0.330, 0.155, 0.159</td>
</tr>
</tbody>
</table>

Note: TRV for Livestock = NOAEL from test species * SF for livestock

Where:
- TRV: Toxicity reference value
- NOAEL: No observable adverse effect level.
- SF: Scaling factor; from Sample and Arenal 1999 = (BW<sub>test species</sub> / BW<sub>animals</sub>)<sup>0.25</sup>
- BW<sub>test species</sub>: Body weight for test species; from Sample et al., 1996.
- BW<sub>animals</sub>: Body weight for livestock; from Table 1 and Table 2.
- kg: Kilograms.
- mg/kg-bw/day: Milligrams per kilogram body weight per day.
- UF: Uncertainty factor to extrapolate from LOAEL to NOAEL

- LMW PAH: Low molecular weight polycyclic aromatic hydrocarbon; LMW PAHs have ≤ 3 rings and molecular weight ≤ 192 atomic mass units (napthalene to phenanthrene).
- HMW PAH: High molecular weight polycyclic aromatic hydrocarbon; HMW PAHs have ≥ 4 rings and molecular weight ≥ 202 atomic mass units (pyrene to dibenz(a,h)anthracene).

* Navarro et al. 1991; For naphthalene from Table 2.
* Navarro et al. 1991; For naphthalene from Table 2.
* McKenzie and Angevine 1981; For benzo(a)pyrene from Table 2.
### Table 7. Polycyclic Aromatic Hydrocarbon (PAH) TRVs and RBSLs for Livestock

<table>
<thead>
<tr>
<th>Receptor</th>
<th>BW (kg)</th>
<th>LMW PAH TRV (mg/kg·bw/day)</th>
<th>HMW PAH TRV (mg/kg·bw/day)</th>
<th>IR&lt;sub&gt;water&lt;/sub&gt; (L/day)</th>
<th>dw-RBSL (mg/L)</th>
<th>LMW PAH RBSL (mg/kg)</th>
<th>HMW PAH RBSL (mg/kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dairy Cattle</td>
<td>540</td>
<td>0.798</td>
<td>0.160</td>
<td>95.0</td>
<td>4.53</td>
<td>0.907</td>
<td>2.42</td>
</tr>
<tr>
<td>Beef Cattle</td>
<td>454</td>
<td>0.833</td>
<td>0.167</td>
<td>86.0</td>
<td>4.40</td>
<td>0.880</td>
<td>2.13</td>
</tr>
<tr>
<td>Calves</td>
<td>50.0</td>
<td>1.45</td>
<td>0.289</td>
<td>36.0</td>
<td>2.01</td>
<td>0.402</td>
<td>0.235</td>
</tr>
<tr>
<td>Sheep</td>
<td>56.7</td>
<td>1.40</td>
<td>0.280</td>
<td>14.0</td>
<td>5.68</td>
<td>1.14</td>
<td>0.595</td>
</tr>
<tr>
<td>Goat</td>
<td>29.5</td>
<td>1.65</td>
<td>0.330</td>
<td>10.0</td>
<td>4.87</td>
<td>0.974</td>
<td>0.354</td>
</tr>
<tr>
<td>Camel</td>
<td>600</td>
<td>0.777</td>
<td>0.155</td>
<td>16.5</td>
<td>28.3</td>
<td>5.65</td>
<td>1.82</td>
</tr>
<tr>
<td>Horse</td>
<td>550</td>
<td>0.794</td>
<td>0.159</td>
<td>42.0</td>
<td>10.4</td>
<td>2.08</td>
<td>4.13</td>
</tr>
</tbody>
</table>

**Note:**

- **dw-RBSL** = (TRV X BW) / IR<sub>water</sub>
- **soil-RBSL** = (TRV X BW) / IR<sub>soil</sub>

**Where:**

- **dw-RBSL** = Drinking water risk-based screening level.
- **soil-RBSL** = Soil risk-based screening level.
- **TRV** = Toxicity reference value.
- **BW** = Body weight; from Table 1.
- **IR<sub>water</sub>** = Water ingestion rate during summer; from Table 1.
- **IR<sub>soil</sub>** = Soil ingestion rate; from Table 1.
- **HMW PAH** = High molecular weight polycyclic aromatic hydrocarbon; HMW PAHs have ≥ 4 rings and molecular weight ≥ 202 atomic mass units (pyrene to dibenz(a,h)anthracene).
- **LMW PAH** = Low molecular weight polycyclic aromatic hydrocarbon; LMW PAHs have ≤ 3 rings and molecular weight 192 atomic mass units (naphthalene to phenanthrene).
Uncertainty Analysis

Uncertainty plays an important role in risk-based decision-making and needs to be incorporated explicitly into risk characterization. Identifying known sources of uncertainty is more useful than using conservative default assumptions because potential error is made more explicit in the risk management process (Suter, 1993).

The TRVs and RBSLs developed in this report were based on a general approach. Various conservative assumptions were made and may have overestimated the threshold values for the protection of livestock. The following assumptions, uncertainties, and safety factors were made or used in the development of TRVs and RBSLs:

5.1 Exposure Assumptions
Most of the exposure assumptions (Table 1) were based on conservative values from available literature sources. For example, for the composition of livestock diet, maximum soil percentages were selected from all available values which subsequently resulted in high soil ingestion rates.

For livestock receptors where exposure parameters were not available, the most conservative value from the other livestock receptors were used. For example, percentage of soil in the diet of camels and horses were based on the percentage of soil in the sheep diet and was the most conservative value.

Similarly, when calculating drinking water RBSLs for livestock, summer drinking water estimates were used (higher value) instead of the winter drinking water estimates (lower value).

Another conservative assumption made was the use of SUF for both complete and significant exposure pathways (i.e., via drinking water and incidental soil ingestion). SUFs for calculating drinking water RBSL and soil RBSL were set at a value of 1 assuming that the livestock receptor will be present at the contaminated site 100% of the time and feeding exclusively on that particular contaminated site media (i.e., water or soil). In cases where the contamination area, such as from leaks, are smaller than the grazing area of the livestock receptors, an SUF of 1 overestimates the threshold values for the protection of livestock.

5.2 Development of TRVs and RBSLs
Factors such as UFs (Equation 2) and SFs (Equation 6) were used in the development of some of the TRVs for livestock and also contribute to the conservative approach used in this report.

For the protection of livestock, TRVs were developed based on chronic NOAELs. For unavailable NOAELs, LOAELs were extrapolated to NOAELs using an UF of 10 (EPA 1999). Note that toxicity studies for only two of the petroleum hydrocarbons (toluene and xylene) report NOAELs as endpoints. The rest of the petroleum hydrocarbons (crude oil, benzene, ethylbenzene, LMW PAH, and HMW PAH) reported LOAELs as endpoints.

Additionally, due to the lack of toxicity studies available for livestock, TRVs for all the petroleum hydrocarbons except crude oil were developed based on toxicity studies on small mammals. A SF was used to allometrically adjust for the difference in body weight between the test species and the livestock receptors.
For crude oil and LMW PAHs, the TRVs and RBSLs were developed based on more toxic test chemicals, unweathered whole crude oil and naphthalene, respectively. Risks estimated for livestock exposed to weathered crude oil or other LMW PAHs using the TRVs and RBSLs developed in this report for these petroleum hydrocarbons would be considered conservative.

The conservative approach used in this report was confirmed in an external peer-review by Dr. Billy R. Clay (MS, DVM; from the American Board of Veterinary Toxicology), stating specifically that the body weight of calves that may be potentially exposed to petroleum hydrocarbons would weigh more than 50 kgs thereby suggesting that 100 kgs would be more appropriate. Additionally, he stated that water ingestion rates used in this report were also quite high for cattle, thereby suggesting that 50 L/day – 60 L/day would be more appropriate (Clay 2003).
6. Analysis of Other Guidelines for Livestock Protection

TRVs and drinking water and soil quality guidelines (i.e. threshold values) for the protection of livestock exposed to petroleum compounds have been developed by two agencies—Canadian Council of Ministers of the Environment (CCME) and Alberta Environment—which are briefly described below. However, there were some limitations and differences in the development of these guidelines from the threshold values developed in this report and are also described below.

6.1 Canada-Wide Standards (CWS; CCME 2000)

The CWS 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 4 fractions of crude oil (CCME 2000). These guidelines present levels considered protective of human and environmental health under 4 generic land uses: agricultural, residential, commercial, and industrial. TRVs for livestock were also developed based on Stober’s (1962) study resulting in value of 210 mg/kg-bw/day similar to the approach described in this report. Drinking water RBSLs were developed using an equation similar to Equation 5a and resulted in a value of 23 mg/L. Values were only presented for the lighter fractions, recognizing that heavier fractions would bind to soil and not migrate to groundwater/surface water. Direct contact, plant ingestion, and inhalation pathways were not addressed by CCME. These toxicity values and guidelines are presented in Table 8.

Differences/Limitations:
- Only TRVs and drinking water RBSLs for livestock were developed and not soil RBSLs.
- Threshold values were not developed for BTEX and PAHs.
- Threshold values were developed for only one livestock receptor (i.e. cattle).
- One element of their approach was the inclusion of an allocation factor (AF) of 0.2 to adjust toxicity and guideline values. This value was used to account for multiple exposure pathways and media exposure (air, soil, water, food, and consumer products) that could be complete at a given site, whereas the guideline values are for single pathways. The AF of 0.2 assumed that livestock can be equally exposed by all 5 potentially complete exposure pathways. However, as discussed in the sections above on the CSM, dermal and inhalation pathways are expected to be minor and not contribute significantly to overall exposure. Additionally, not all sites will have both water and soil exposures. Therefore, for a general approach an AF of 1 would be appropriate with suggestion to use site-specific AFs as warranted to evaluate multiple exposure pathways.
- The fractionation approach by CCME is not necessarily applicable or appropriate at all sites. 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.
- It should be noted that there was an order of magnitude error in calculating the RfC value by CCME and the RFC value should actually be 231 mg/L (this error was acknowledged by CCME; personal communication with Ted Nason, September 10, 2002).

6.2 Alberta Environment (2001)

In 2001, Alberta Environment issued a document that 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
Crude oil TRVs for livestock were not developed specifically for this document but were adopted from CCME (as described above). For BTEX, TRVs were developed using an approach similar to that described in this report based on effects in laboratory animals adjusted by an uncertainty factor. Soil and water RBSLs for crude oil fractions and BTEX were based on these TRVs and exposure parameters with adaptations to Alberta conditions where appropriate. These toxicity values and guidelines are presented in Table 8.

Differences/Limitations:

- TRVs for crude oil fractions were adopted from CCME and therefore, also used an AF of 0.2 (see above for explanation).
- Another element of their approach to calculating soil RBSLs for crude oil fractions was the inclusion of a protection factor of 0.75 to prevent livestock from being exposed to more than 75% of the TRV. Although this may seem protective, as an AF of 0.2 was already used for the TRV, it was likely overly conservative.
- Threshold values were not developed for PAHs.
- Threshold values were developed for only one livestock receptor (i.e., cattle).
- The fractionation approach used by CCME is not necessarily applicable or appropriate at all sites (see above for explanation).
- Two types of water quality guidelines were developed: exposure point guidelines for water to which receptors are actually exposed, and groundwater quality guidelines to assess acceptable concentrations of chemicals in groundwater.
- Additionally, SQGs for the protection of groundwater (i.e., the concentration of chemical in soil that will not cause unacceptable concentrations in surface water) for livestock were also developed using fate and transport models and Alberta-specific groundwater recharge rates.
### Table 8. Other Available Toxicity Values and Guidelines for Livestock

<table>
<thead>
<tr>
<th>PHCs</th>
<th>Whole</th>
<th>F1 (23.2%)</th>
<th>F2 (21.3%)</th>
<th>F3 (34.5%)</th>
<th>F4 (18.2%)</th>
<th>BTEX</th>
<th>PAHs</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Benzene</td>
<td>Toluene</td>
</tr>
<tr>
<td>Canadian Council of Ministers of the Environment (CCME) Toxicity Values and Guidelines (CCME 2000)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TRV (mg/kg-bw/day)</td>
<td>210</td>
<td>9.74</td>
<td>8.95</td>
<td>14.5</td>
<td>9.64</td>
<td>NA</td>
<td>NA</td>
</tr>
<tr>
<td>dw RBSL (mg/L)</td>
<td>231</td>
<td>53.0</td>
<td>49.0</td>
<td>79.0</td>
<td>42.0</td>
<td>NA</td>
<td>NA</td>
</tr>
<tr>
<td>soil RBSL (mg/kg)</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
</tr>
<tr>
<td>Alberta Environment Toxicity Values and Guidelines (Alberta 2001a; 2001b)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TRV (mg/kg-bw/day)</td>
<td>210</td>
<td>9.74</td>
<td>8.95</td>
<td>14.5</td>
<td>9.64</td>
<td>0.0800</td>
<td>4.46</td>
</tr>
<tr>
<td>dw RBSL (mg/L)</td>
<td>1342</td>
<td>62.0</td>
<td>57.0</td>
<td>na</td>
<td>na</td>
<td>0.510</td>
<td>29.0</td>
</tr>
<tr>
<td>gw RBSL (mg/L)</td>
<td>1342</td>
<td>62.0</td>
<td>57.0</td>
<td>na</td>
<td>na</td>
<td>0.510</td>
<td>29.0</td>
</tr>
<tr>
<td>soil RBSL (mg/kg)</td>
<td>9,000</td>
<td>4,000</td>
<td>3,700</td>
<td>6,000</td>
<td>4,000</td>
<td>33.0</td>
<td>1,800</td>
</tr>
<tr>
<td>soil/gwRBSL (mg/kg)</td>
<td>NA</td>
<td>11,000</td>
<td>8,600</td>
<td>na</td>
<td>na</td>
<td>2.20</td>
<td>2.200</td>
</tr>
</tbody>
</table>

F: Fraction of crude oil.
HMW: High molecular weight.
LMW: Low molecular weight.
NA: Not available.

PAHs: Polycyclic aromatic hydrocarbons.
PHCs: Petroleum hydrocarbons.
dw RBSL: Drinking water risk-based screening level.
soil RBSL: Soil risk-based screening level.
TRV: Toxicity reference value; referred to as daily threshold effect dose in CCME 2000 and Alberta 2001a; 2001b.
mg/kg-bw/day: Milligrams per kilogram body weight per day.
mg/kg: Milligrams per kilogram.
mg/L: Milligrams per liter.
%

* TRV for crude oil fractions are fractions of whole crude oil TRV including allocation factor of 0.2 (see text for details).
* Corrected RBSL; CCME reported dwRBSL for crude oil as 23 mg/L (see text for details).
* Adapted from CCME 2000.
* Exposure point guideline; calculated using an equation similar to Equation 4b in the text.
* Groundwater quality guideline; assumed to be the same as exposure point guidelines for livestock (Alberta 2001a; 2001b).
* Soil quality guideline; calculated using an equation similar to Equation 4c including a safety factor of 0.75 (see text for details).
* Soil quality guideline for the protection of groundwater; based on fate and transport models and Alberta specific data (Alberta 2001a; 2001b).
7. Summary

The first step in a livestock risk assessment at a site would be to evaluate the potential for exposure. If no significant and complete exposure pathways exist for petroleum hydrocarbons, there is little to no likelihood of unacceptable risk to livestock from these compounds. Where a complete exposure pathway (or pathways) is determined to exist, the presence or level of risk to livestock from petroleum hydrocarbons depends on several key factors, including exposure route, duration, and dose, chemicals present, species characteristics (i.e., body weight, metabolism, overall health), and factors related to the potential significance of ecological effects, such as the grazing area or range.

The toxicity values and guidelines for crude oil developed in this report for soil ingestion in livestock are comparable to human health risk-based screening levels (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) was developed for groundwater and plants (Hamilton et al., 1999).

To characterize risks to livestock from petroleum hydrocarbon exposure at a site, drinking water and soil RBSLs developed in this report can be used as screening values for soil, surface water, and groundwater for livestock protection. If the effective size of the contamination is available, site-specific RBSLs can also be developed using SUFs in order to estimate potential risks to livestock from exposure to that particular site. If required, a quantitative risk evaluation could be conducted using the TRVs and exposure factors presented in this report. Additionally, cumulative risks can be estimated for livestock receptors exposed to petroleum hydrocarbons via multiple exposure pathways.

The overall approach used to develop threshold values in this report was conservative (Clay 2003) and it can be assumed that risks calculated using the TRVs and RBSLs from this report would definitely be protective of livestock receptors exposed to petroleum hydrocarbons.
8. References


