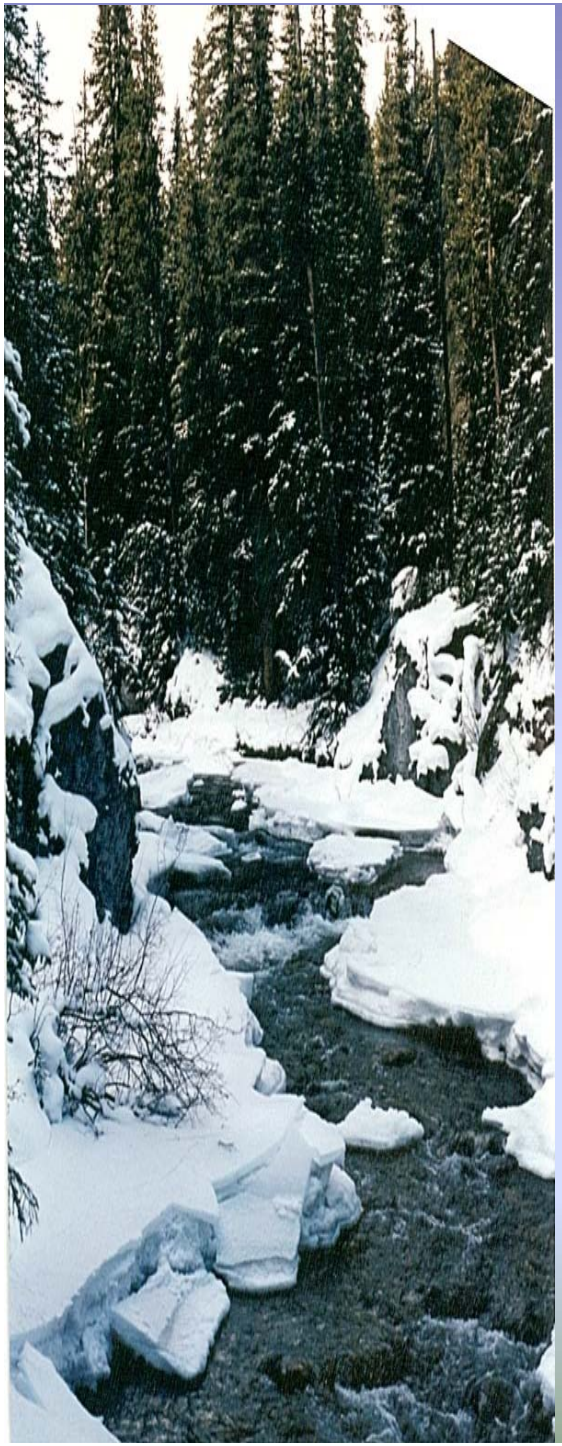

Equilibrium Environmental Inc.

Exova

New Tier 1 Boron Guideline for Alberta: Overall Guideline Development

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- Exova
- Petroleum Technology Alliance of Canada (PTAC)
- PTAC Boron Working Group
- Environment Canada
- Alberta Environment

Presentation Overview

- Background
- Boron Sorption and K_d Values
- Guideline Derivation for Soil Dependent Biota
- Livestock and Wildlife Toxicity
- Groundwater Pathways and Guidelines
- Other Soil Pathways and Guidelines
- Summary of Proposed Tier 1 Soil Remediation Guidelines

Background

- Current Tier 1 guideline of 2 mg/kg HWS ('hot water soluble') boron an 'interim' guideline from 1991 based on professional judgment
- Good plant growth has been observed in the field and lab at levels above the current Tier 1 guideline
  - e.g, 4-10 mg/kg HWS or higher for typical soils - see previous Exova presentation
- Saturated paste B (in mg/L) is more closely correlated to plant toxicity than HWS B over a range of soil textures
  - HWS B test was designed to diagnose deficiency, not toxicity
- Saturated paste B represents boron dissolved in soil solution, HWS B captures large amounts of adsorbed boron
- Cases with background soils above the Tier 1 HWS guideline can be distinguished from impacted soils using saturated paste B
- Saturated paste B also relevant to groundwater transport and various groundwater pathways

→Other background information summarized in previous Exova presentation (Remtech, 2015)

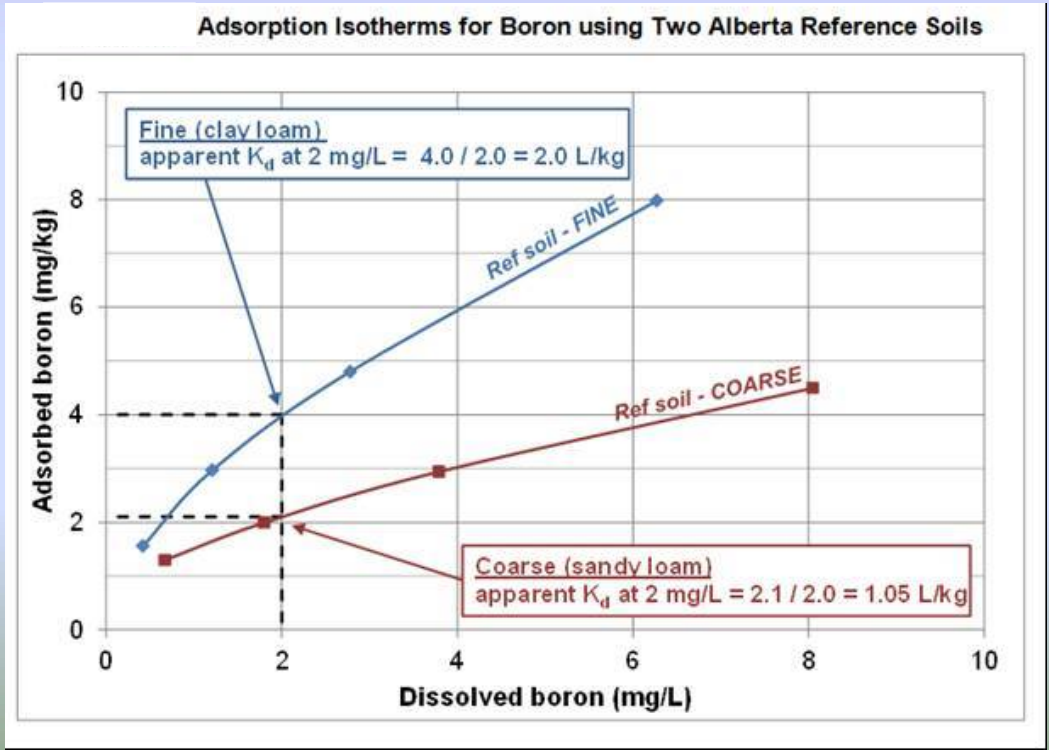
Boron Sorption and K_d Values

Boron Adsorption in Soil – K_d Aspects

- K_d is related to partitioning of boron between soil and pore water (soil solution)
- Soils with high clay content or organic matter content have greater surface area and thus higher sorptive ability
  - Adsorption is thus correlated to soil texture
- Sorption is commonly explored via a distribution coefficient, K_d which is defined as:

$$K_d = \frac{\textit{adsorbed boron (mg/kg)}}{\textit{dissolved boron (mg/L)}}$$

K_d often measured with batch adsorption isotherm experiments (example for Alberta reference soils)

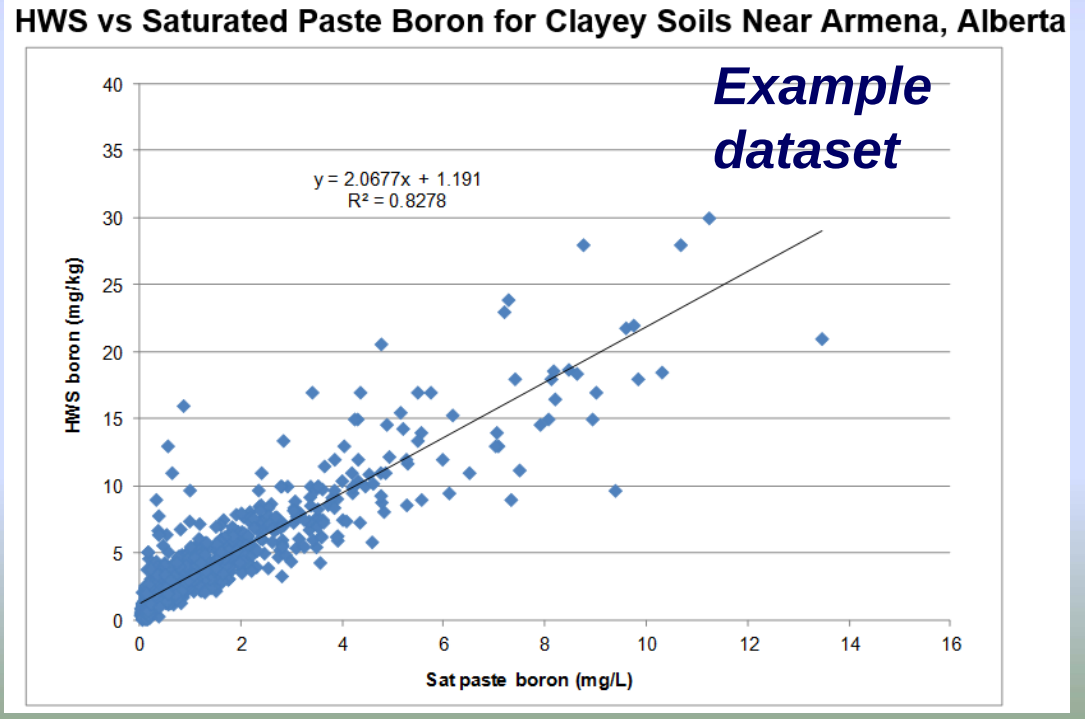


Boron Adsorption in Soil – K_d Aspect

- **Sorbed B cannot easily be measured directly, but the HWS test is a good proxy**
  - **HWS B → measures sorbed B plus dissolved B**
  - **Sat paste B → measures dissolved B**
- **Often useful to plot HWS B (mg/kg) vs sat paste B (mg/L) for site data as indicator of soil sorption and allows estimation of K_d**

K_d can be estimated from slope:

$$\frac{\text{HWS B (mg/kg)}}{\text{sat paste B (mg/L)}} = K_d + \frac{\text{Sat\%}}{100}$$



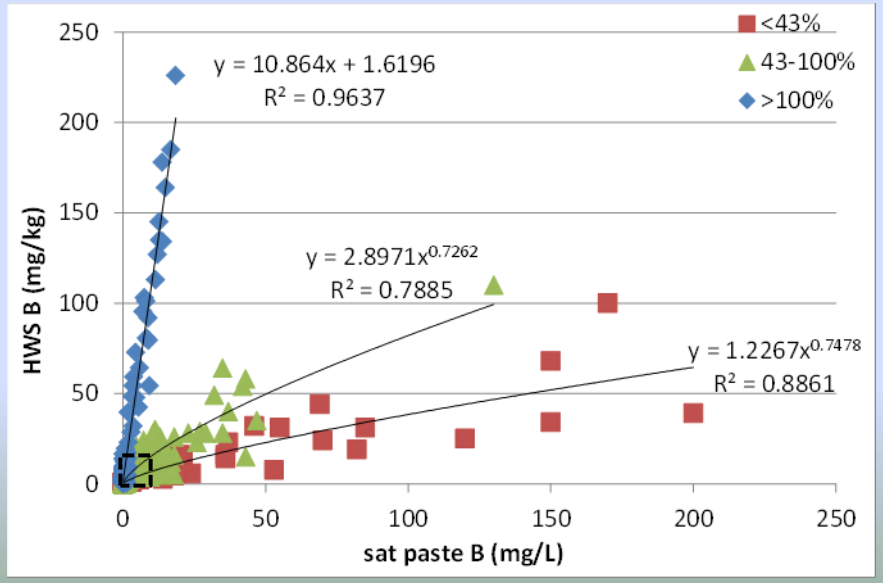
Boron Adsorption in Soil – K_d Aspect

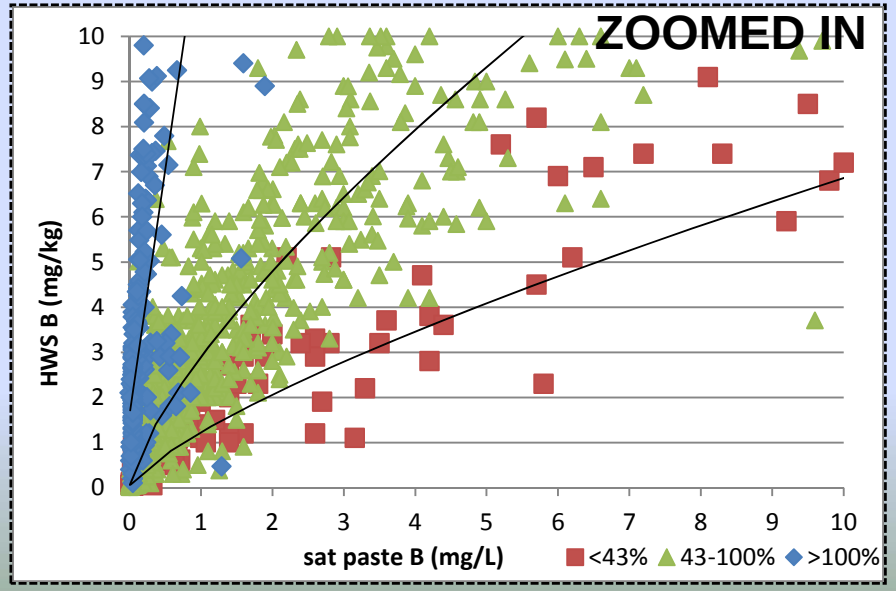
- Used this technique for over 2,300 data points from over 40 sites across Alberta spanning a range of soil textures
- K_d correlated to texture via saturation percentage

(sat % a proxy for texture, see Equilibrium 2014 PTAC presentation)

Estimated K_d values for Typical Alberta Soils

Saturation percentage range	Typical texture	Average K_d (L/kg)	Average saturation percentage
>100%	Heavy clay or organic soils	8.5	374%
43-100%	Fine clayey soils	2.1	61%
<43%	Coarser or silty soils	0.8	34%

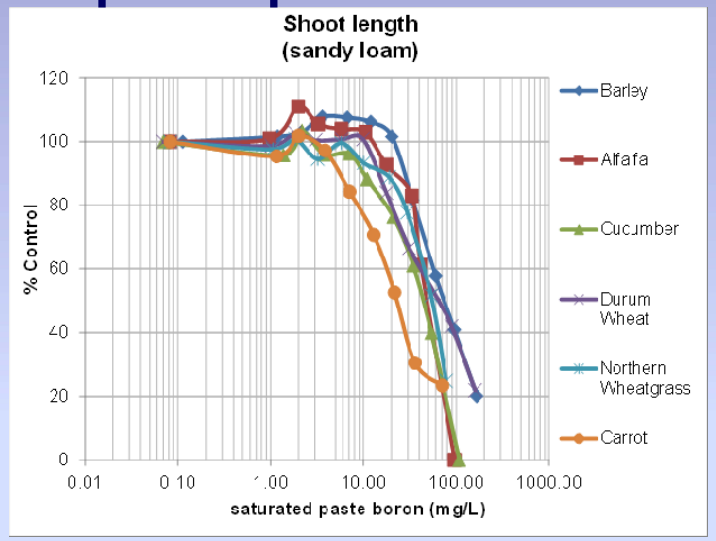


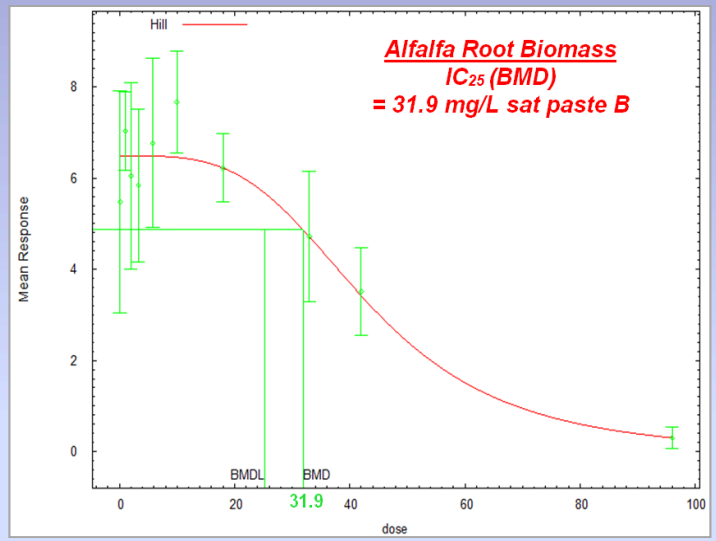


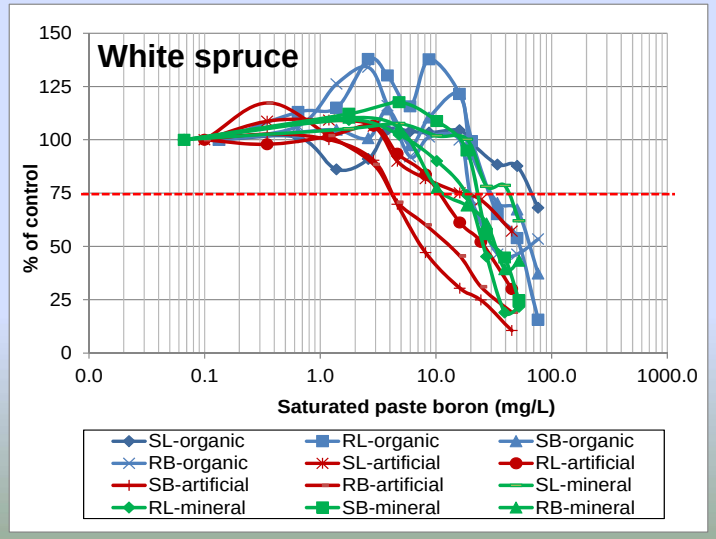
Guideline Derivation for Soil Dependent Biota

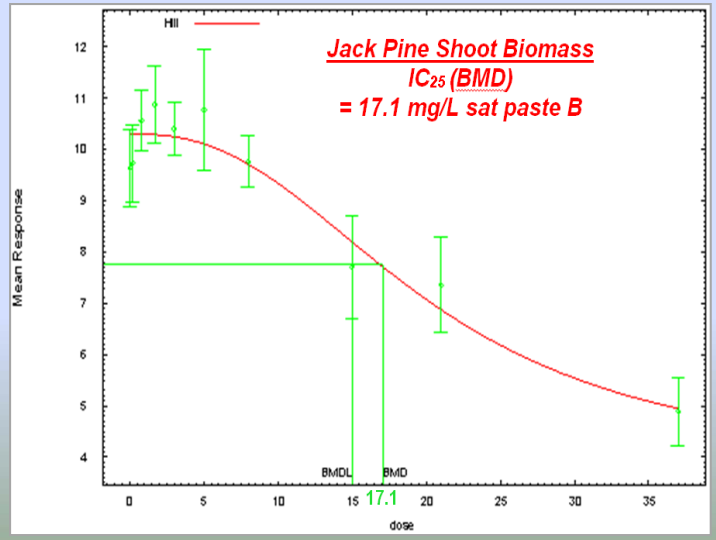
Soil Dependent Biota – Plants (Exova)

- **Recent toxicity studies carried out by Exova on Agricultural and Boreal plant species (See Exova 2015 Remtech presentation). Example responses and 25% effect levels shown below**



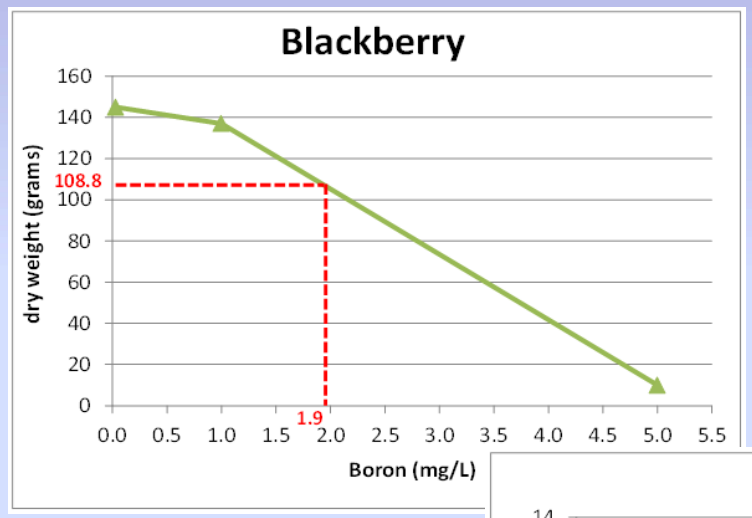




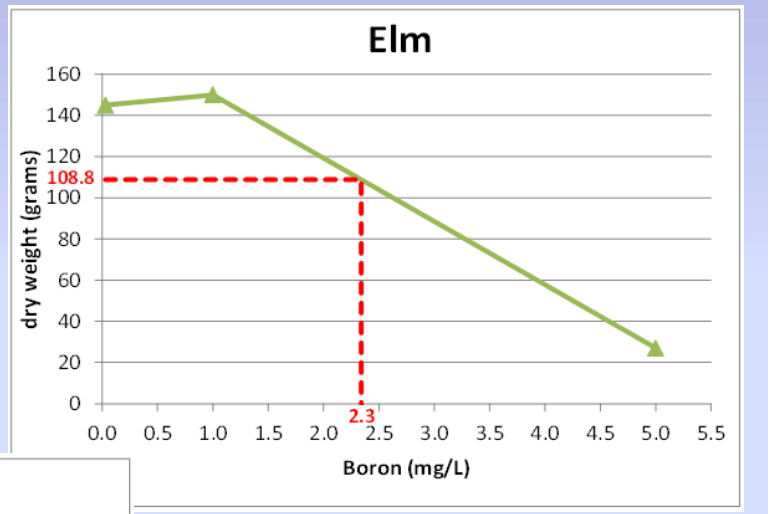


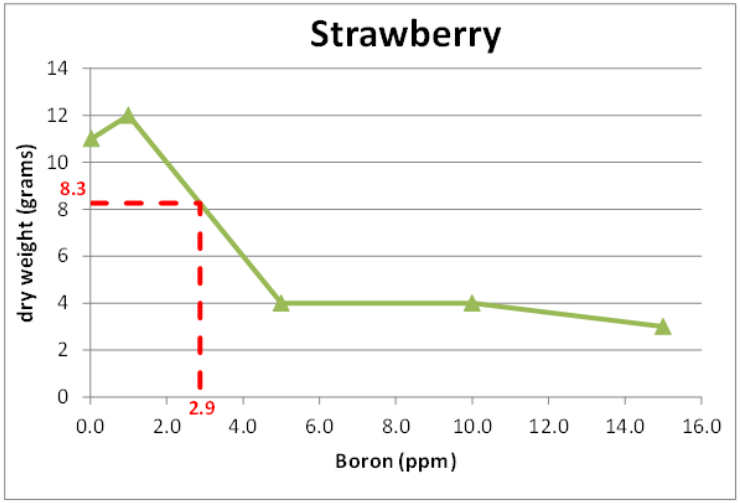
Soil Dependent Biota – Plants (literature)

- Toxicity research in California by Eaton (1944) on various fruit, vegetable and grass/grain species in sand cultures irrigated with boron at 0, 1, 5, 10, 15 mg/L.
- Visual effects and changes in biomass recorded
- IC_{25}'s estimated for cases where clear dose-response observed



Examples





Soil Dependent Biota – Plants (literature)

- More recent sand culture experiments carried out on additional food-crops, and to refine threshold levels from the 1944 results
- Slopes and thresholds useful for estimating 25% effect levels (IC_{25}'s)

Summary of Plant Species Thresholds, Slopes and Calculated IC_{25}'s from Newer Sand Culture Experiments

Common Name	*Botanical Name*	Tolerance Based on	Threshold B (mg/L)	Slope (%/mg·L^{-1})	Calculated IC_{25} (mg/L)	Sensitivity Rating	Reference	Test Duration
Barley	*Hordeum vulgare*	Grain yield	3.4	4.4	9.1	moderately tolerant	Bingham et al., 1985	6 months
Bean, snap	*Phaseolous vulgaris*	Pod yield	1	12	3.1	sensitive	Francois, 1989	2.5 months
Broccoli	*Brassica oloracea* (Botrytis group)	Head fresh weight	1	1.8	14.9	moderately sensitive	Francois, 1986	3.5 months
Cauliflower	*Brassica oloracea* (Botrytis group)	Curd fresh weight	4	1.9	17.2	moderately tolerant	Francois, 1986	3.5 months
Celery	*Apium graveolens var. dulce* (Mill.) Pers	Petiole fresh weight	9.8	3.2	17.6	very tolerant	Francois, 1988	4.5 months
Cowpea	*Vigna unguiculata* Walp.	Seed yield	2.5	12	4.6	moderately tolerant	Francois, 1989	2-3 months
Garlic	*Allium sativum*	Bulb yield	4.3	2.7	13.6	tolerant	Francois, 1991	7.5 months
Lettuce	*Lactuca sativa*	Head fresh weight	1.3	1.7	16.0	moderately sensitive	Francois, 1988	3.5 months
Onion	*Allium cepa*	Bulb yield	8.9	1.9	22.1	very tolerant	Francois, 1991	7.5 months
Radish	*Raphanus sativus*	Root fresh weight	1	1.4	18.9	moderately sensitive	Francois, 1986	1.5 months
Sorghum	*Sorghum bicolor* Moench	Grain yield	7.4	4.7	12.7	very tolerant	Bingham et al., 1985	4 months
Squash, Scallop	*Cucurbita pepo* var melopepo Alef	Fruit yield	4.9	9.8	7.5	tolerant	Francois, 1992	1.5 months
Squash, Winter	*Cucurbita moschata* Poir	Fruit yield	1	4.3	6.8	moderately sensitive	Francois, 1992	3 months
Squash, zucchini	*Cucurbita pepo* var melopepo Alef	Fruit yield	2.7	5.2	7.5	moderately tolerant	Francois, 1992	1.5 months
Sugar beet	*Beta vulgaris*	Storage Root fresh weight	4.9	4.1	11.0	tolerant	Vlamis & Ulrich, 1973	1.5 months
Tomato	*Lycopersicon lycopersicum* Karst. Ex Farw.	Fruit yield	5.7	3.4	13.1	tolerant	Francois, 1984b	3-4 months
Wheat	*Triticum aestivum*	Grain yield	0.75-1.0 [1]	3.3	8.3	sensitive	Bingham et al., 1985; Khudairi, 1961	6 months

Soil Dependent Biota – Soil Invertebrates

- Soil invertebrates such as earthworms, springtails and mites are important receptors in soil, along with plants
- Recent Exova research in combination with toxicity data from published literature and method development studies was combined to derive IC_{25}'s across species and soil types
  - Substantial work done by Environment Canada, Method Development Unit
- Reproductive endpoints used to derive IC_{25}'s are shown below as an example of the invertebrate dataset
- In many cases sat paste boron estimated from spiked levels and regressions. For Exova tests, sat paste B measured directly

Invertebrate Boron Toxicity – 25% Effect Data on Reproductive Endpoints

	Species	Test	Duration	Soil	Measure	Boron (B) added (mg/kg)	sat paste Boron (mg/L)	Reference
Earthworm	Esenin andrei	reproduction	63 days	sandy loam	IC25	*	**26.4**	* Exova, 2013
Earthworm	Dendrodrilus rubidus	reproduction	56 days	artificial	IC25	47	**13.5**	Environment Canada, 2008-2010
Earthworm	Eisenia andrei	reproduction	84 days	clay loam	IC25	28	**13.1**	Ingraldi, 2004
Oribatid mite	Oppia nitens	reproduction	28 days	artificial	IC25	44	**12.0**	Environment Canada, 2006-2010
Springtail	Proisotoma minuta	reproduction	21 days	artificial	EC25	37	**9.4**	Environment Canada, 2010-2012
Earthworm	Eisenia andrei	reproduction	63 days	sandy loam	IC25	*	**5.4**	* Exova, 2013
Springtail	Folsomia candida	reproduction	28 days	artificial	IC25	27	**5.6**	Environment Canada, 2007c
Oribatid mite	Oppia nitens	reproduction	28 days	loam with 2-7% OM	IC25	13	**5.1**	Princz, 2010
Springtail	Folsomia fimetaria	reproduction	21 days	clay loam	IC25	13	**4.7**	CECOTOX, 2005
Earthworm	Eisenia andrei	reproduction	84 days	clay loam	IC25	12	**4.4**	Ingraldi, 2004
Springtail	Folsomia fimetaria	reproduction	21 days	artificial	IC25	15	**2.4**	CECOTOX, 2005

Guideline to Protect Soil Dependent Biota

- **Direct eco-contact guideline derived based on the ranked IC_{25}s for all soil dependent biota which includes:**
  - **-Agricultural plants (crops, grasses, trees, fruits, vegetables)**
  - **-Boreal plants (trees, grasses, other plants)**
  - **-Soil invertebrates (earthworms, mites, springtails)**
- **Coarse and fine grained soil generally combined since similar responses on sat paste B basis**
- **The IC_{25}s for soil dependent biota were plotted in a species sensitivity distribution (SSD). Guidelines determined from best fit to toxicity data SSD (log-linear distribution):**

Agricultural, Natural, Residential/Parkland (25th percentile):

Direct eco-contact guideline = 3.3 mg/L sat paste B

Commercial/Industrial (50th percentile):

Direct eco-contact guideline = 8.2 mg/L sat paste B

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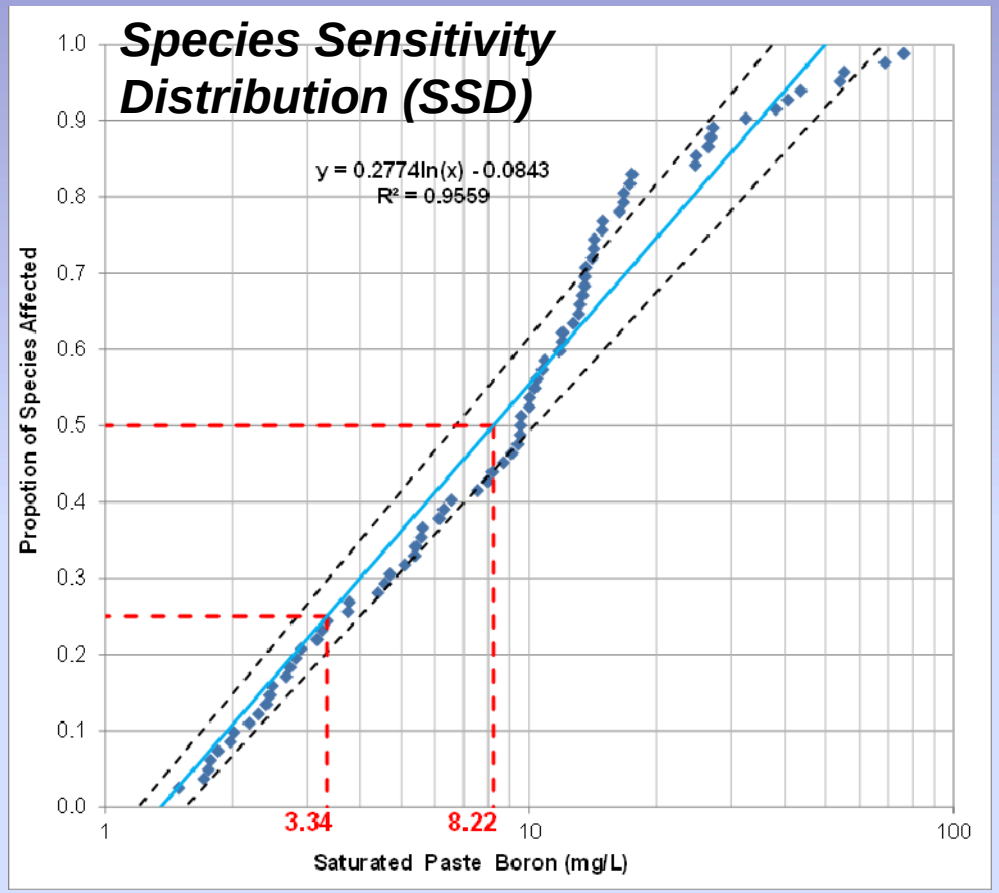
Soil Dependent Biota – Combined Ranked IC_{25}s

Description	IC_{25} (mg/L sat paste B)	Rank	CCME rank percentile
Oasis nibens (A)	76.31	81	0.99
Folsomia fimetaria (A)	69.92	80	0.98
Eisenia andrei (CL)	65.22	79	0.98
Folsomia fimetaria (CL)	63.06	78	0.05
Barley - shoots (CL, SL)	43.80	77	0.94
Alfalfa - roots (CL, SL)	40.89	76	0.93
Alfalfa - shoots (C.., SL)	39.21	75	0.91
Folsomia fimetaria (A)	32.39	74	0.90
N. Wheatgrass - shoots (CL, SL	27.10	73	0.89
Oppia nitens (L)	26.01	72	0.88
Eisenia andrei (SL)	25.40	71	0.87
Durum wheat - shoots (CL, SL)	24.73	70	0.85
White spruce - shoots (MN)	24.03	69	0.84
Onion (S Cu)	17.47	68	0.83
Mustard (S Cu)	17.26	67	0.82
Vetch (S Cu)	16.70	66	0.80
Barley - roots (CL, SL)	16.66	65	0.79
Oxalis (S Cu)	16.29	64	0.78
Celery (S Cu)	14.94	63	0.77
White spruce - roots (MN)	14.66	62	0.76
Carrot - roots (CL, SL)	14.23	61	0.74
Durum wheat - roots (CL, SL)	14.10	60	0.73
N. Wheatgrass - roots (CL, SL)	14.00	59	0.72
Cauliflower (S Cu)	13.80	58	0.71
Carrot - shoots (CL, SL)	13.63	57	0.70
Dendrobaena rubicua (A	13.60	56	0.68
Oppia nitens (L)	13.36	55	0.67
Cabbage (S Cu)	13.16	54	0.66
Eisenia andrei (CL)	13.10	53	0.65
Folsomia fimetaria (CL)	12.89	52	0.63
Oasis nibens (A)	12.00	51	0.62
Lettuce (S Cu)	11.99	50	0.61
Broccoli (S Cu)	11.78	49	0.60
Beet (S Cu)	10.87	48	0.59
Grain (S Cu)	10.76	47	0.57
Radish (S Cu)	10.44	46	0.56
Jack pine - roots (MN)	10.30	45	0.55
Soybean (S Cu)	10.04	44	0.54
Tomato (S Cu)	10.02	43	0.52
Jack pine - shoots (MN)	9.57	42	0.51
Parsely (S Cu)	9.03	41	0.50
California poppy (S Cu)	9.01	40	0.49
Protostrongylus rufescens (A)	9.40	39	0.48
Kentucky bluegrass (S Cu)	9.10	38	0.46
Sugar beet (S Cu)	8.77	37	0.46
Cucumber - shoots (CL, SL)	8.22	36	0.44
Potato (S Cu)	7.98	35	0.43
Bluejoint - roots (MN)	7.53	34	0.41
Common wheat (S Cu)	6.63	33	0.40
Bluejoint - shoots (MN)	6.29	32	0.39
Oats (S Cu)	6.13	31	0.38
Folsomia candida (A)	6.80	30	0.37
Alfalfa (S Cu)	6.68	29	0.35
Eisenia andrei (SL)	6.43	28	0.34
Squash (S Cu)	6.38	27	0.33
Oppia nitens (L)	6.13	26	0.32
Folsomia fimetaria (CL)	4.73	25	0.30
Cucumber - roots (C.., SL)	4.67	24	0.29
Eisenia andrei (CL)	4.43	23	0.20
Barley (S Cu)	3.77	22	0.27
Carrot (S Cu)	3.74	21	0.26
Corn (S Cu)	3.35	20	0.24
Larkspur (S Cu)	3.25	19	0.23
Pea (S Cu)	3.13	18	0.22
Sweet pea (S Cu)	2.90	17	0.21
Lima bean (S Cu)	2.82	16	0.20
Zinnia (S Cu)	2.73	15	0.18
Jerusalem Artich (S Cu)	2.68	14	0.17
Kid bean (S Cu)	2.48	13	0.16
Snap bean (S Cu)	2.45	12	0.15
Folsomia fimetaria (A)	2.41	11	0.13
Crop pea (S Cu)	2.31	11	0.12
Peach (S Cu)	2.19	9	0.11
Violet (S Cu)	2.02	8	0.10
Strawberry (S Cu)	1.98	7	0.09
Cherry (S Cu)	1.85	6	0.07
Grass (S Cu)	1.79	5	0.06
Elm (S Cu)	1.75	4	0.05
Lupine (S Cu)	1.71	3	0.04
Blackberry (S Cu)	1.49	2	0.02
[illegible]	0.63	1	0.01
25th percentile (from SSD)	3.34	--	--
50th percentile (from SSD)	8.22	--	--



25th percentile (from SSD)	3.34
50th percentile (from SSD)	8.22

**Subject to final regulatory approval*

Livestock and Wildlife Toxicity

Livestock and Wildlife Soil & Food Ingestion

- Grazing animals may be exposed to elevated boron and other metals which have accumulated from soil into consumed vegetation
- Boron is less toxic to grazers than some other metals such as molybdenum and selenium, but in some cases naturally occurring boron can be ingested at potentially toxic levels. <u>Examples:</u>
- Sheep in Kazakhstan grazing on soils with highly-elevated natural boron were observed to have symptoms of toxicity (enteritis)

- Lambs in the Kulundinsk Steppe in Russia grazing on soils with highly-elevated natural boron also observed to have symptoms of toxicity

- Mallards in the San Joaquin Valley in California exposed to high boron (and selenium) levels in surface waters in irrigated regions

West San Joaquin Valley – 'Red Rock Ranch' showing residual salts including selenium and boron

Image from: 'http://californiaagriculture.ucanr.org/landingpage.cfm?Article=ca.v063 n01p 41&fulltext=yes'

Livestock and Wildlife Soil & Food Ingestion

- **Toxicity data from literature reviewed for rats, mice, cattle, chickens, mallards, rabbits, etc**
- **Variability of data between the studies poses challenges in deriving IC_{25}s. For example: limited dose ranges, study duration, unavailable feed rate or body weight information, lack of reproductive data, lack of clear dose response relationships, etc.**

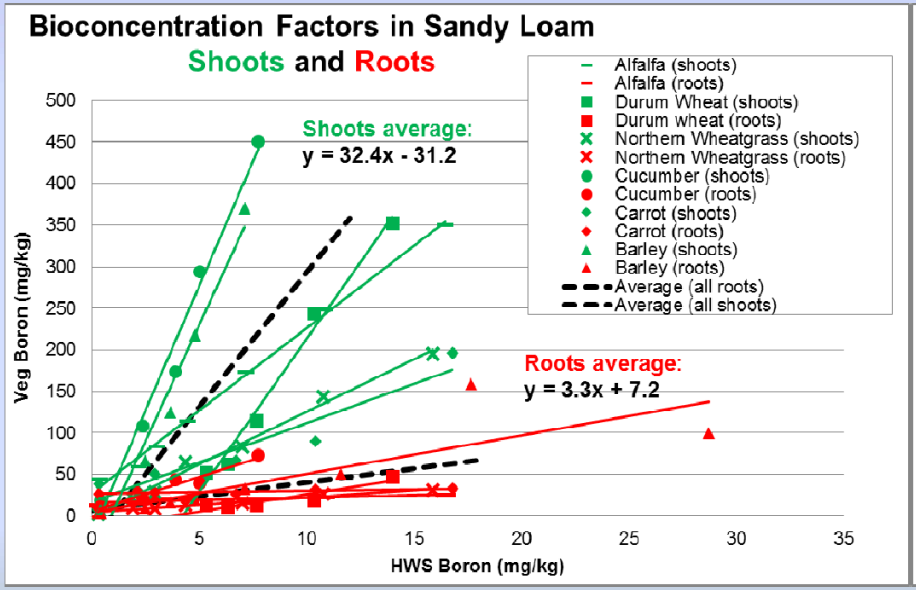
→ toxicity data deemed more appropriate for identifying general ranges or the absence/onset/presence of effects, but is insufficient for identifying quantitative EC_{25} levels for a sufficient range of sensitive endpoints and relevant species as per CCME (2006) protocol.

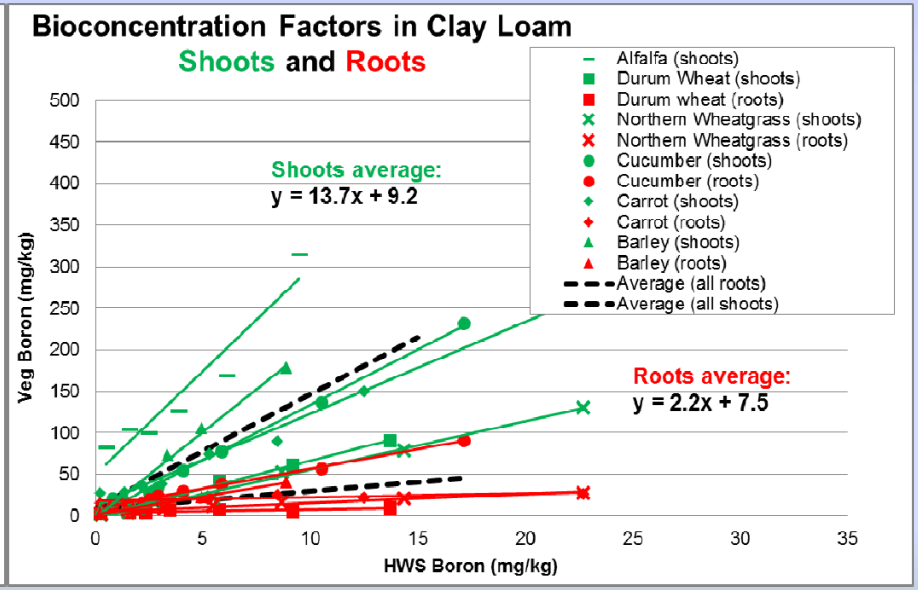
Thus, a guideline for protection of livestock and wildlife soil and food ingestion is not explicitly derived, rather exposures and risks have been evaluated for typical species assuming soils at the direct eco-contact guideline for plants/invertebrates

Livestock and Wildlife Soil & Food Ingestion

- B uptake into plants described by 'bioconcentration factors' (BCF's)
- Estimated daily exposures to B calculated from soil at 3.3 mg/L sat paste using vegetation BCF's

  BCF = vegetation boron (mg/kg) / soil boron (mg/kg HWS boron)
- BCF's vary with soil texture if using HWS B. Differences become less if using sat paste B (mg/L) instead, but BCF's typically calculated on mg/kg basis and thus retained here





- Average BCF (roots and shoots combined) is 15.5 for coarse soil and 9.6 for fine soil, consistent with other AB field and tub studies

Livestock and Wildlife Soil & Food Ingestion

- Assuming soil at 3.3 mg/L sat paste B, typical HWS values estimated as 4.8 mg/kg (coarse soil) or 7.0 mg/kg (fine soil) HWS
  - based on reference soils - will vary site-to-site depending on soil type
- Vegetation boron concentrations of 74 mg/kg (coarse) and 67 mg/kg (fine) estimated from the BCF's from previous slide
- Expected daily exposures for various livestock/wildlife species calculated, and compared to various estimated toxicity thresholds from literature
- Relative exposures shown as exposure ratios

Species	Body Weight	Food Ingestion Rate	Exposure		Daily dose for no/minimal effects	Toxicity endpoint	Primary reference	Exposure ratio	
			fine	coarse				fine	coarse
	kg	kg/day	mg/kg-day	mg/kg-day	mg/kg-day			-	-
rats	0.24	0.021	6.0	6.6	10.3	$BMDL_{05}$ (reduced fetal weight)	US EPA, 2004a,b	**0.58**	**0.64**
mice	0.028	0.0036	8.8	9.7	43	NOAEL (reduced fetal success, body weight, malformations)	Heindel, 1992, 1994	**0.20**	**0.22**
chickens	3.7	0.14	2.5	2.7	10.9	NOAEL/LOAEL (reduced hatchability, damaged sperm cells)	Rossi, 1993a	**0.23**	**0.25**
cattle	550	12.3	1.5	1.7	5.5	NOAEL (increased phosphate excretion)	Weeth, 1981	**0.27**	**0.30**
rabbits	3.5	0.19	3.7	4.1	22	NOAEL (reduced fetal success, malformations)	Heindel, 1994	**0.17**	**0.19**
mallards	1.1	0.062	3.8	4.2	14.6	NOAEL (reduced brain ATP levels and activity levels)	Hoffman, 1990	**0.26**	**0.29**

All exposure ratios <1

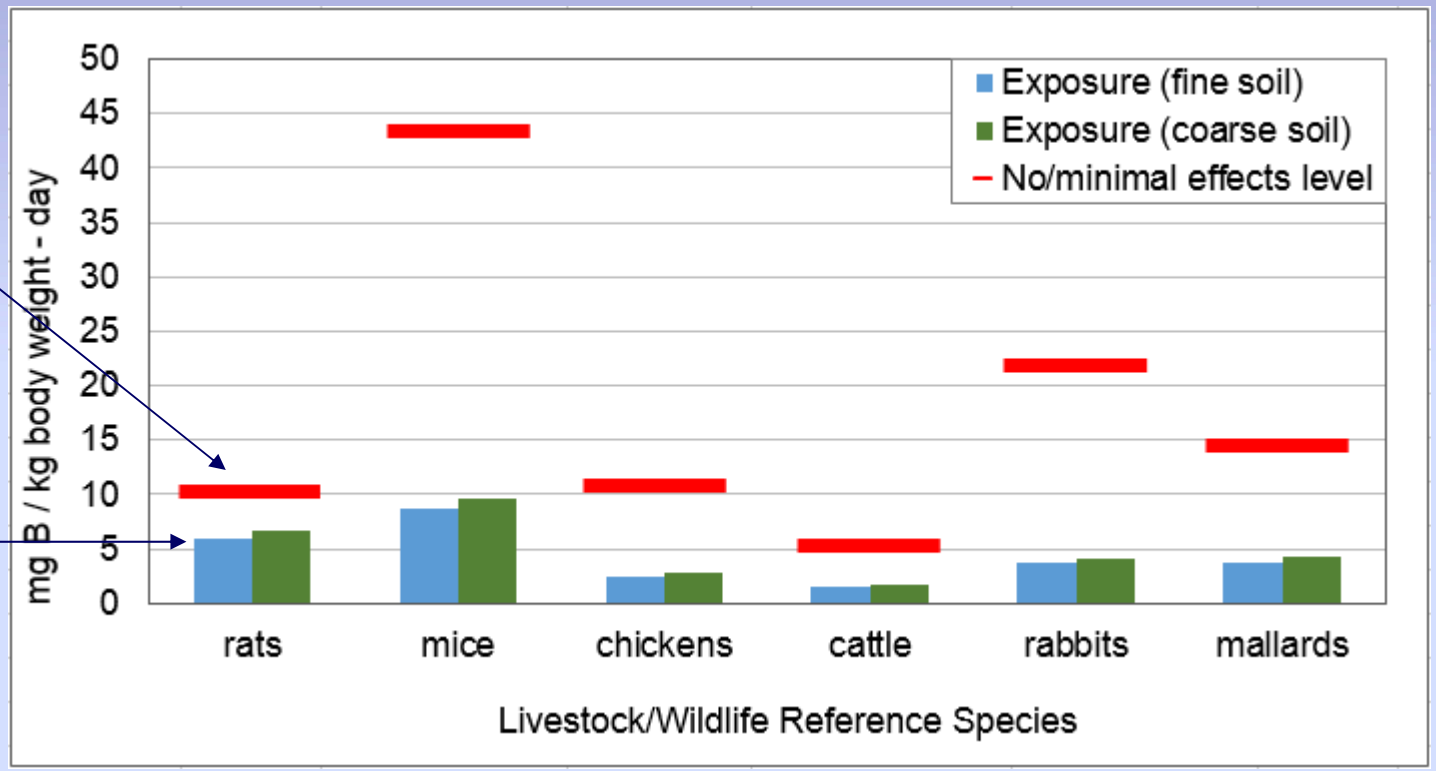
Livestock and Wildlife Soil & Food Ingestion

- **Shown graphically, all exposures ratios are <1**

(*i.e.*, below thresholds) –implies minimal risk from food

No/minimal effect doses (from literature tox studies)

Estimated daily exposures from consuming plants grown in soil at 3.3 mg/L sat paste B



- **Exposure to B from soil ingestion negligible compared to food**
- **Exposure to B in drinking water assumed to be 25% of threshold**
- **All exposure ratios below 0.75 (75%), indicating minimal risk to livestock and wildlife from food, soil, and water**

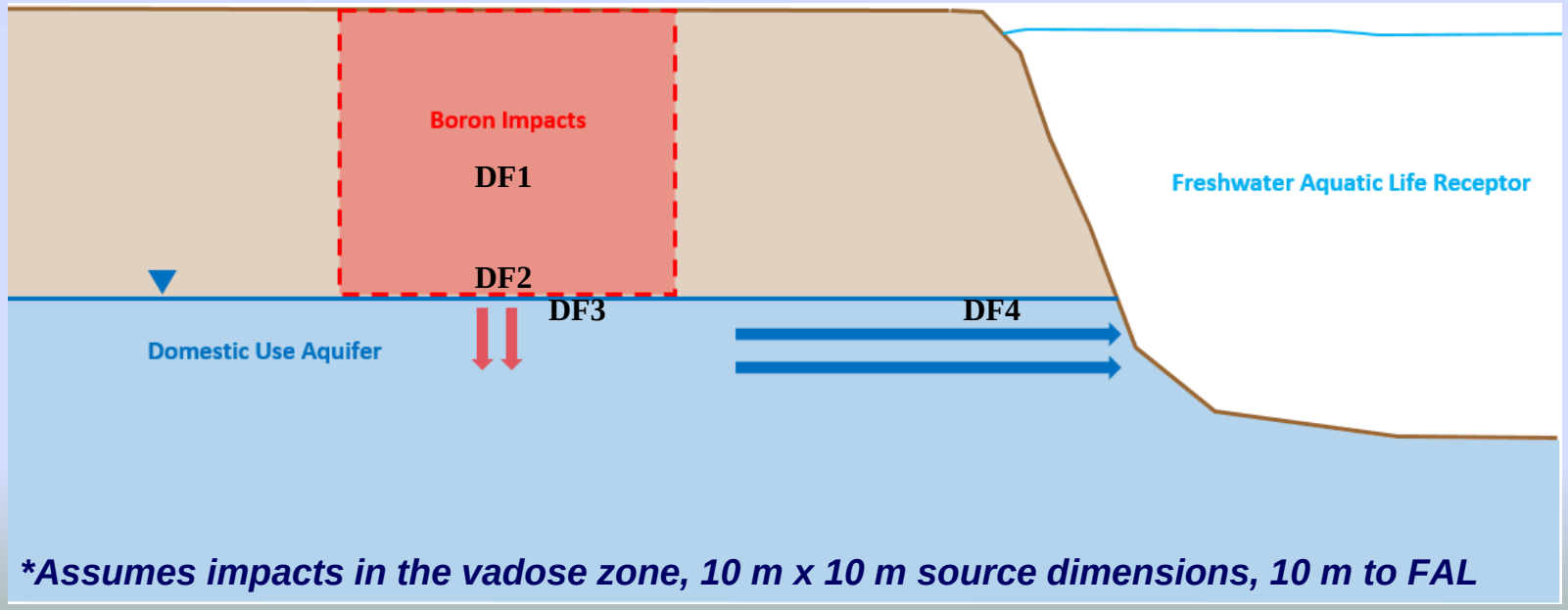
Groundwater Pathways and Guidelines

SRGs to Protect Groundwater Pathways

- **Groundwater boron guidelines can be converted to generate SRGs in mg/L sat paste, to protect groundwater pathways such as:**
  - **Irrigation water** **- Human drinking water**
  - **Aquatic life** **- Livestock drinking water**
- **Uses Alberta Environment Tier 1 methodology;**

  →GW guideline x DF1 x DF2 x DF3 X DF4

AENV Dilution Factors (DF1, DF2, DF3, DF4):



**Assumes impacts in the vadose zone, 10 m x 10 m source dimensions, 10 m to FAL*

SRGs to Protect Groundwater Pathways

DF1: Partitioning:

- The DF1 equation below has been modified from the Tier 1 protocol to express the ratio between saturated paste boron and soil solution boron at a given soil moisture content. It is based on estimated K_d values
- A typical DF1 for fine soil is 0.823 and for coarse soil is 0.767

$$DF1 = \frac{Saturated\ paste\ B\ (mg/L)}{Soil\ solution\ \ B\ (mg/L)} = \frac{K_d + \frac{\theta_w}{\rho_b}}{K_d + \frac{saturation\ \%}{100}}$$

where:

$DF1$	=	modified dilution factor 1 (dimensionless)
K_d	=	distribution coefficient (L/kg)
θ_w	=	water-filled porosity (dimensionless);
ρ_b	=	dry soil bulk density (kg/L);

DF2: Vertical transport through vadose zone:

- =1, assumes impacts immediately above water table

DF3: Dilution into fine or coarse groundwater:

- ~3-5, depends on pathway and soil texture. Higher for DUA pathway

DF4: Lateral biodegradation/dispersion to aquatic life:

- ~1, very little dispersion during 10 m travel. No degradation

Guideline for Irrigation Water

- **Alberta Tier 1 and surface water documents show a range of 0.5-6 mg/L for irrigation water B thresholds based on older sand culture experiments**
  - **Irrigation water <1 mg/L appears to pose minimal risk**
- **Assuming a groundwater boron guideline of 1 mg/L, fine and coarse SRGS shown below:**

Irrigation water pathway	Fine texture	Coarse texture
Groundwater guideline	1 mg/L	1 mg/L
DF1	0.823	0.767
DF2	1	1
DF3	3.86	4.64
Soil guideline (saturated paste boron)	**3.18 mg/L**	**3.56 mg/L**

- **Since similar for both textures, average of the fine and coarse guidelines used as overall guideline for irrigation water:**

  Irrigation water guideline = 3.4 mg/L saturated paste B

**** Tier 2 adjustments may be required if source length is >10 m***

Guideline for Aquatic Life

- **Alberta Tier 1 guideline for aquatic life is 1.5 mg/L for surface water / groundwater**
- **Soil guideline for protecting aquatic life derived similarly as for irrigation water using DF equations**
  - **Assumes 10 m to receptor**

Aquatic life pathways	Fine texture	Coarse texture
Groundwater guideline	1.5 mg/L	1.5 mg/L
DF1	0.823	0.767
DF2	1	1
DF3	3.86	4.64
DF4	1	1
Soil guideline (saturated paste)	**4.76 mg/L**	**5.34 mg/L**

- **Since similar for the two textures, average of the fine and coarse guidelines used as overall guideline:**

Aquatic life guideline = 5.0 mg/L saturated paste B

**** Tier 2 adjustments may be required if source length is >10 m***

Guidelines for Livestock and Wildlife Water

- **Alberta Tier 1 guideline for livestock and wildlife water is 5 mg/L for groundwater / surface water**
- **Soil guideline derived in same manner using DF equations:**

Livestock watering pathways	Fine texture	Coarse texture
Groundwater guideline	5 mg/L	5 mg/L
DF1	0.823	0.767
DF2	1	1
DF3	3.86	4.64
DF4	1	1
Soil guideline (saturated paste)	**15.88 mg/L**	**17.78 mg/L**

- **Since similar for the two textures, average of the fine and coarse guidelines is the overall guideline:**
  Livestock / wildlife water guideline = 16.8 mg/L sat paste B

**** Tier 2 adjustments may be required if source length is >10 m***

Guideline for DUA

- **Alberta Tier 1 guideline for DUA (human drinking water) is 5 mg/L for groundwater**
- **Soil guideline derived in same manner using DF equations:**

Human drinking water pathways	Fine texture	Coarse texture
Groundwater guideline	5 mg/L	5 mg/L
DF1	0.823	0.767
DF2	1	1
DF3	15.93	30.87
Source concentration (saturated paste)	**65.5 mg/L**	**118.3 mg/L**

- **The fine and coarse soil guidelines are maintained separately for the DUA pathway since values differ by approximately 2-fold:**

DUA guideline = 66 mg/L sat paste B (fine)

DUA guideline = 118 mg/L sat paste B (coarse)

**** Tier 2 adjustments may be required if source length is >10 m and has substantial effects on DUA pathway***

Other Soil Pathways and Guidelines

Guideline for Human Direct Soil Contact

- Boron a reproductive toxin in humans and other animals
- Boron toxicity to humans via occupational exposure or accidental poisoning described in literature, but data is sparse/anecdotal
- Detailed toxicity studies commonly performed on proxy laboratory species such as rats, mice, and rabbits
  - rats found to be the most sensitive species based on decreased fetal weight

- A human health oral reference dose of 0.2 mg/kg-day has been developed by the US EPA (2004) based on rat toxicity data and uncertainty/safety factors
  - more recent than Health Canada value from 1990
- Human direct soil contact guidelines estimate exposure from ingested, inhaled, and dermally absorbed boron from soil
- Relatively low-risk pathways under typical circumstances:

Agricultural, Residential / Parkland:

Human direct soil contact guideline = 7,500 mg/L sat paste B

Commercial / Industrial:

Human direct soil contact guideline = 234,000 mg/L sat paste B

Guidelines for Offsite Migration

- **Soil guidelines derived to protect soil dependent biota and humans from offsite migration of boron from commercial/industrial land to more sensitive adjacent land uses such as agricultural**
  - **Migration considered to be via wind-blown soil**
  - **Guidelines applicable to commercial/industrial land only**

Ecological soil contact: derived from agricultural eco-contact SRG of 3.3 mg/L saturated paste.

Off-site migration (eco-contact) = 45.9 mg/L sat paste B

Human soil contact: derived from agricultural human direct soil contact SRG of 7,500 mg/L saturated paste.

Off-site migration (human contact) = 107,000 mg/L sat paste B

Summary of Proposed Tier 1 Boron Guidelines

- **Constrained by ecological direct soil contact (plants and invertebrates) for most land uses including agricultural**
- **Constrained by aquatic life for commercial/industrial land use**
- **Groundwater pathways may require Tier 2 adjustments, could alter constraining pathways**

Receptor	Overall Guideline		Human				Ecological												
Pathway			Direct Soil Contact	Protection of Domestic Use Aquifer		Off-Site Migration	Direct Soil Contact		Livestock Soil and Food Ingestion	Wildlife Soil and Food Ingestion	Protection of Freshwater Aquatic Life		Protection of Livestock Water		Protection of Wildlife Water		Protection of Irrigation Water		Off-Site Migration
Soil Type	Fine	Coarse		Fine	Coarse		Fine	Coarse			Fine	Coarse	Fine	Coarse	Fine	Coarse	Fine	Coarse	
Unit	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
Natural	3.3	3.3	-	65	118	-	3.3	3.3	-	-	5.0	5.0	-	-	17	17	-	-	-
Agricultural	3.3	3.3	7,500	65	118	-	3.3	3.3	-	-	5.0	5.0	17	17	17	17	3.4	3.4	-
Residential/ Parkland	3.3	3.3	7,500	65	118	-	3.3	3.3	-	-	5.0	5.0	-	-	-	-	-	-	-
Commercial	5.0	5.0	230,000	65	118	110,000	8.2	8.2	-	-	5.0	5.0	-	-	-	-	-	-	46
Industrial	5.0	5.0	230,000	65	118	110,000	8.2	8.2	-	-	5.0	5.0	-	-	-	-	-	-	46

Note: all boron guidelines expressed on a mg/L saturated paste boron basis

**** Subject to final regulatory approval***

Thank You

Questions?

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- Exova
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- Environment Canada
- Alberta Environment