Study to determine allowable "Salt" concentration in Permitted Landfarms

OCD Exhibit 9 - Part 2
Case 13586
April 20, 2006

Salt Risk Assessment Review

- *Human Health Impacts- Low Threat*
- *Groundwater Impacts- Medium Threat*
- *Ecological Impacts- Highest Threat*

Proposed Rule 53 for surface waste management facilities (old rule 711) is presently being re-evaluated to determine the effects of salt contaminated soils placed in these type of facilities. Landfarms are facilities designed to remediate hydrocarbon contaminated soils. All oilfield waste has some residual salt content, in particularly drilling cuttings can have extremely high salt contents (*e.g.;* >100,000 ppm) which would basically sterilize the soil and prevent any bio-activity. In addition, these salts may present a future threat to the surface and underlying water.

OCD's environmental staff has been given the task to determine what salt levels would be protective of the environment when placed in these type of facilities. OCD has researched other states such as Michigan, Kansas, and Texas to compare regulations and values.

OCD researched the issue of a salt closure standard that is protective of the environment. OCD approached this problem as follows:

1. OCD Modeled the chloride ion since it is generally considered non-adsorbing, highly soluble, and very mobile.

2. OCD used EPA's and ASTM's "best thinking to date" soil screening guidance for the nation for the protection of groundwater.

3. OCD compared the results from the API Vadsat model with EPA's guidance using New Mexico data.

4. OCD focused on ground water protection and compared steady state infinite source models considered to be very conservative to an inter-active transient finite source model.

5. OCD also considered information submitted by the Chloride Working Group "Draft Proposal."

6. OCD also reviewed information from other state programs.

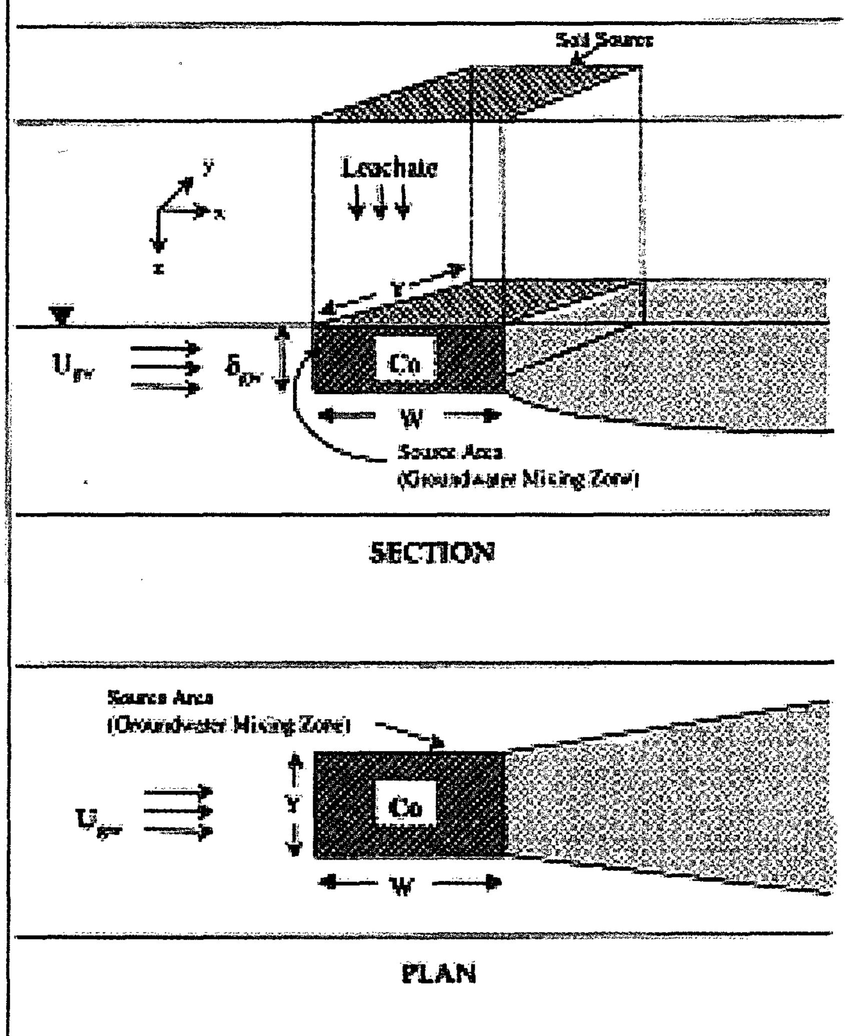

Figure 4-3: SCHEMATIC DESCRIPTION OF DOMENICO'S MODEL

Chloride Model Study

See spreadsheet

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Proposed Rule 53 for surface waste management facilities (old rule 711) is presently being re-evaluated to determine the effects of salt contaminated soils placed in these type of facilities. Landfarms are facilities designed to remediate hydrocarbon contaminated soils. All oilfiled waste has some residual salt content, in particularly drilling cuttings can have extremely high salt contents I.e. 100,000 ppm which would basically sterilize the soil and prevent any bio-activity. In addition, these salts may present a future threat to the surface and underlying water.

OCD's environmental staff has been given the task to determine what salt levels would be protective of the environment when placed in these type of facilities. OCD has researched other states such as Michigan, Kansas, and Texas to compare regulations, values and/or quantity of salts allowed to remain in the ground and still be protective of the environment. OCD approached the problem utilizing the following criteria:

1. Modeling the chloride ion of salts since they are generally considered non-adsorbing, highly soluble, and very mobile.
2. Using EPA's and ASTM "best thinking to date" soil screening guidance for the nation for the protection of groundwater.
3. Utilizing API Vadsat modeling program to compare with EPA's guidance and use New Mexico's site specific data.
4. Focusing on groundwater protection by comparing steady state infinite source models considered to be very conservative to an inter-active transient finite souce model.
5. Included information submitted by the Chloride Working Group "Draft Prposal"
6. Other state programs

OCD utilized the API's vadsat model and the following input parameters were selected with a brief explanation:

Landfill typical parameters:

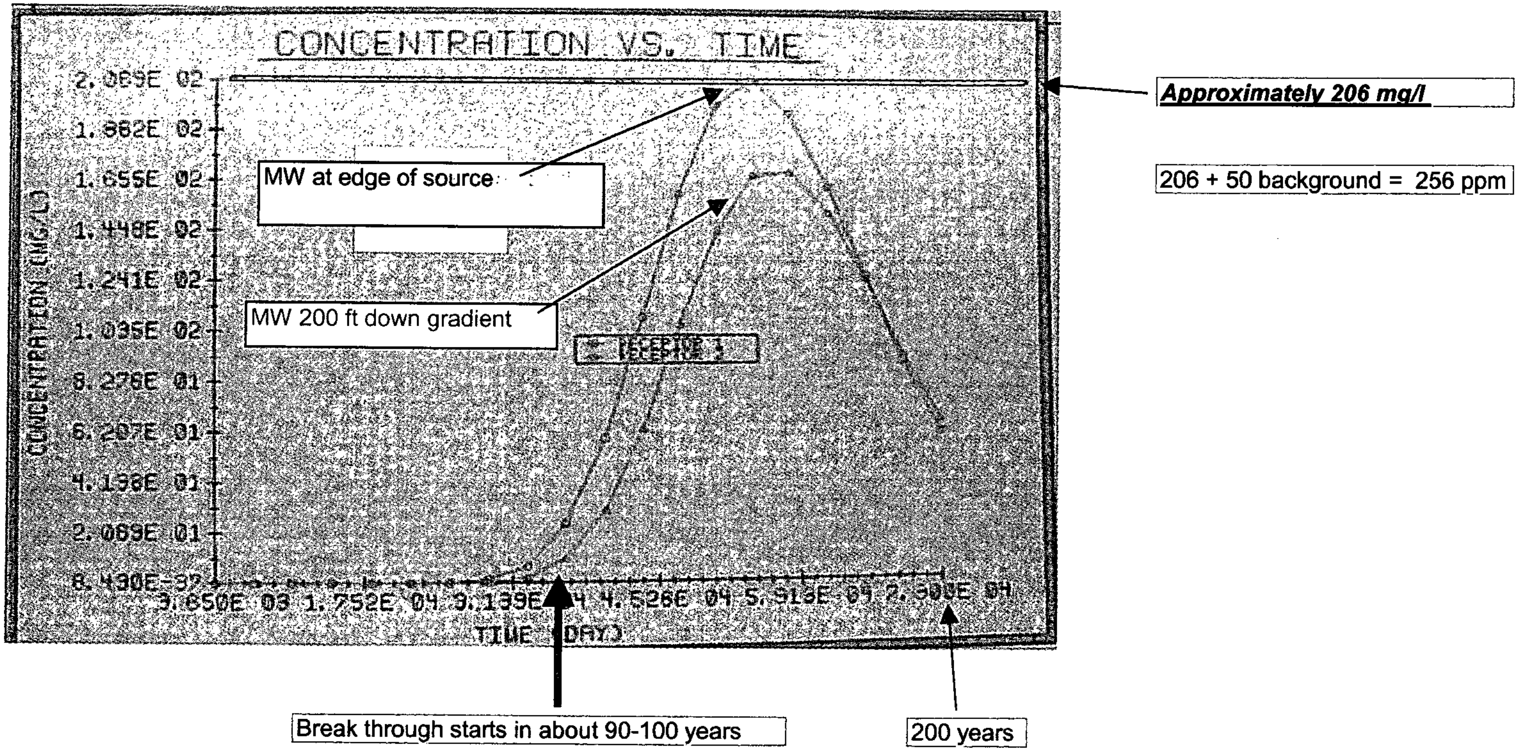
Cell size:	**5 acres**
Depth of waste:	**2 feet**
Minimum depth to groundwater:	**50 feet**
Liners:	**none**
Waste Type:	**salt contaminated soil-like material @ 1000 mg/kg**
Location:	**Lea County, NM**
Hydrologic Input:	**Ogallala**
	USGS/NM State Engr. Study Report #84-4062
	Groundwater Recharge in the Southern High Plains.

American Petroleum Institute (API) VADSAT Modeling Program:

A Vadose and Saturated Zone Transport Model for Assessing the Effects on Groundwater Quality from Petroleum Production Waste.

INPUT Parameters:

Waste Type:	*Soil with salt*								
Model Period:	*200 years*								
source:	*5 acres*	*1000 mg/kg*		*square 465'x465'*	*waste zone thickness 2 feet.*		*no liners*		
vadose zone:	*48 feet*	*bio-na*	*OC-na*	*Sand Hycond .888 m/d*	*Por .43*	*VG=2.68*	*Rwater = .045*		*VertDis-yes*
Groundwater:	*10 feet*	*bio-na*	*OC-na*	*Sand Hycond .888 m/d*	*Por .30*	*Ldis-yes*	*L/Tdis-=3*	*T/Vdis=87*	*Gradient = .01*
Net Infiltration:	*.38 in/yr*								
Receptors:	*1 ft*	*200 ft*							



206 + 50 background = 256 ppm

EPA Steady-State Infinite Source Model

Tier 1 Evaluation of the soil to groundwater pathway for chlorides.

Soil Screening Level in Soil (mg/kg)

RBSLsoils = GW standard (250 mg/l) x (DAF) x (water filled porosity) / (soil dry density)

Cw =	Ground water protection standard (mg/L) x	dilution factor			
GW standard	250 mg/L	250			
Kd =	Soil water partition coefficient = 0 for salts	0			
Ow =	water-filled soil porosit default = .3	0.3	EPA default		
Pb =	dry soil bulk density kg/L	1.5	EPA default		
dilution factor =	1 + Kid/IL				

USGS/NM State Engineer study of the Ogallala Aquifer report # 84-4062

			range of input parameters		
K =	Aquifer hydraulic conductivity ft/yr	14600	16 ft/day	40 ft/day	155 ft/day
I	hydraulic gradient ft/ft	0.0023		12 ft / mile	
d =	groundwater mixing zone depth ft	10		typical MW	
I =	Infiltration rate ft/yr	0.032	0.25 in/yr	.38 in/yr	.50 in/yr
L =	Length of source parallel to GW ft	463		5 acres	

df	auto	equation	0.04226	
		DAF	23.66469	
SSL	auto	equation	1183 mg/kg	**results**

Chloride Working Group Tier 1 Evaluation of the soil to Groundwater Pathway for Chlorides-Draft 5/23/01

Objective: Develop a New Mexico Tier 1 screening value for chlorides in soil that is protective of GW and is acceptable to operators and regulators. The screening value could be used as a practical limit for delineation.

Proposed Approach: ASTM (NMRBCA) simple fate and transport moleding.

Assumptions:

1. 250 mg/l will be threshold for groundwater protection.
2. Salt in soil above 5 feet below grade surface will tend to move upward due to NM high evaporation rates.
3. Recharge is extreanely low in NM. I.e. .25 cm/yr. Data complied by DB Stephens throughout NM.
4. No siting or restrictions on location.
5. State wide data for GW Darcy velocity Ugw = 51 ft/year
6. GW mixing zone thickness = 10 ft
7. Size of site was 50 feet parallel to GW flow. No width was given. Width was assumed to be 1 ft.
8. Infiltration rate was set 10 times for safety which was 1.16 in per yr.

ASTM equations: ***RBSLs = (RBSLgw) X (Ks/LF)*** ***ASTM E2081-00***

LF (dilution factor in groundwater) = 1/ (1 + Ugw X MZt)/ (I x W)
where Ugw is GW Darcy velocity
where MZt is mixing zone thickness
where I is infiltration rate (recharge)
where W is length of the GW source

RBSLgw is groundwater to be protected NM standard is 250 mg/l.
Ks is the total soil concentration to pore water concentration ratio and is given Ksw= (Ow+Kd*Ps + (Heff*Oa)/ Ps
where Ow is the water filled porosity of the unsaturated zone
where Kd soil water partition coefficient
where Ps is dry soil bulk density
Oa is the soil air content

Heff and Kd was set to = 0

1938 ***mg/kg*** ***Chloride Working Group*** ***with a DAF of 109***

EPA standard is 20 for small sites less than .5 acre

EPA Default Dilution-Attenuation Factor (DAF) Study

EPA/540/R-96/018 July 1996 second edition
March 08, 1990 (55 Federal Register 8666.

DAF is defined as the ratio of contaminant concentration in soil leachate to the concentration in groundwater at the receptor point.

Assumptions:

1. Infinite source results in all subsurface adsorption sites being eventually filled and no longer available to attenuate contaminants.
2. Soil contamination extends to the water table, eliminating attenuation process in the unsaturated zone.
3. The receptor well is assumed to be at the down gradient edge of the source, minimizing the opportunity fot attenuation in the aquifer.
4. EPA does not believe that it is possible at this time to incorporate degradation processes into simple site-specific methodology for national applications.
5. The aquifer is unconfined and unconsolidated and has homogeneous and isotropic properties.
6. May not be applicable to fractured rock or karst aquifer types.
7. Simple dilution model does not consider facilitated transport. I.e. transport via solvents other than water.

EPA used the EPACMTP finite element model to evaluate over 1300 sites throughout the nation.
Monte Carlo model applications using probability distributions were performed for each input parameter. At the conclusion of the analysis a cumulative frequency distribution of DAF values was constructed and plotted.
Degradation and retardation of contaminants were not considered

The table below is an excerpt from the study.

values are based on empirical data reflecting a national sample distribution of depth of residential drinking water wells). The location of the intake point allows for mixing within the aquifer. EPA believes that this is a reasonable assumption because there will always be some dilution attributed to the pumping of water for residential use from an aquifer. The horizontal placement of the well was assumed to vary uniformly along the center of the downgradient edge of the source within a width of one-half of the width of the source. Degradation and retardation of contaminants were not considered in this analysis. Figure 3 is a schematic showing aspects of the subsurface SSL conceptual model used in the EPACMTP modeling effort. Appendix E is the background document prepared by EPA/OSW for this modeling effort.

EPACMTP Model Results. The results of the EPACMTP analyses indicate a DAF of about 170 for a 0.5-acre source at the 90th percentile protection level (Table 5). If a 95th percentile protection level is used, a DAF of 7 is protective for a 0.5-acre source.

Table 5. Variation of DAF with Size of Source Area for SSL EPACMTP Modeling Effort

Area (acres)	DAF 85th	DAF 90th	DAF 95th
0.02	1.42E+07	2.09E+05	946
0.04	9.19E+05	2.83E+04	211
0.11	5.54E+04	2.74E+03	44
0.23	1.16E+04	644	15
0.50	2.50E+03	170	7.0
0.69	1.43E+03	120	4.5
1.1	668	60	3.1
1.6	417	38	2.5
1.8	350	33	2.3
3.4	159	18	1.7
4.6	115	13	1.6
11.5	41	5.5	1.2
23	21	3.5	1.2
30	16	3.0	1.1
46	12	2.4	1.1
69	8.7	2.0	1.1

5 acres

15

Dilution Factor Modeling Effort. To gain further information on the national range and distribution of DAF values, EPA also applied the simple SSL water balance dilution model to ground water sites included in two large surveys of hydrogeologic site investigations. These were American Petroleum Institute's (API's) hydrogeologic database (HGDB) and EPA's database of conditions at Superfund sites contaminated with DNAPL.

The HGDB contains the results of a survey sponsored by API and the National Water Well Association (NWWA) to determine the national variability in simple hydrogeologic parameters (Newell et al., 1989). The survey was conducted to validate EPA's use of the EPACML model as a screening tool for the land disposal of hazardous wastes. The survey involved more than 400 ground

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Selecting the 90 th percentile which is in mid-range of the table results and a 5 acre source, by extrapolating a DAF of 15 would be appropriate for such a site.

If 250 mg/l is the protractible groundwater standard then the soil screening level would be calculated as follows:

Ct = 250 x DAF 15) x Ow (water filled porosity)/ Ps (dry bulk density)

EPA default for Ow = .3 and Ps = 1.5

Ct = 750 mg/kg

Conclusion:

The following is a summary of all of the soil screening levels calculated above and averaged.

Vadsat	1000 mg/kg		
EPA infinite source model	1183 mg/kg	if over 50 feet from groundwater	1000
ASTM (RBCA) Chloride working group	1983 mg/kg		1153
EPA DAF study	750 mg/kg	**very small source	1953 700
Total	4916/4 = 1229 mg/kg		~~1027~~ compensated for ~~1215~~Cl backround levels 1209

adjusted to include a background concentration of 50 mg/l in groundwater. The other three models were not adjusted for background levels.
found to be very close When the other three models are adjusted for chloride background levels the average of these values is a 2 foot waste zone that is approximately 50 feet from groundwater.

OCD's default value. *1000 mg/kg*

Chloride Soil Screening Levels in Other Areas

Groundwater Protection

Michigan	*500*-2500-5000 ppm*
Texas(oily waste)	*<3000 ppm and EC < 4 mmhos/cm*
Kansas	*1000 ppm*

Chloride Soil Screening Levels in Other Areas

- ***Michigan   500*-2500-5000 ppm***
- ***Texas (oily waste) <3000 ppm and EC < 4 mmhos/cm***
- ***Kansas 1000 ppm***

Chloride Test vs EC /SAR Test

- Chloride Extraction vs Saturated Paste
- Extractions are more accurate when different types of soil are involved (as much as 10:1)
- Saturated Paste is easy and quick and produces good results when used with similar soils
- Chloride Extraction field kits produces results very similar to Laboratory methods
- SARs are generally run in Lab

Ecological Receptors

- Soil Invertebrates
- Plants
- Aquatic Species- NA

ROYAL ROADS UNIVERSITY

Derivation of Matrix Soil Standards for Salt under the British Columbia Contaminated Sites Regulation

June 2002

Report to the British Columbia
Ministry of Water, Land and Air Protection,
Ministry of Transportation and Highways,
British Columbia Buildings Corporation, and the
Canadian Association of Petroleum Producers

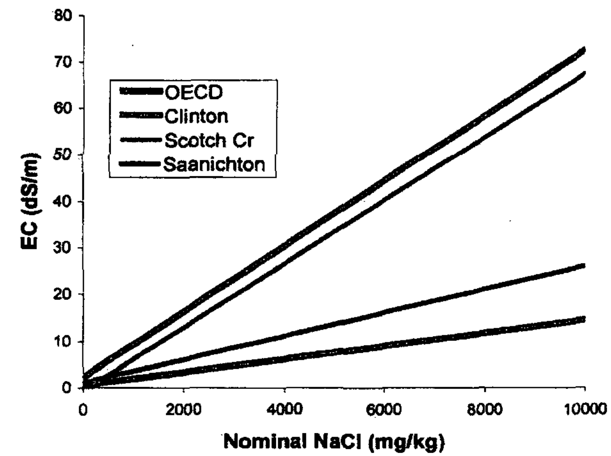

Figure 5.1: Relationship Between Electrical Conductivity and Nominal Concentrations of NaCl in Four Experimental Soils.

Table 5.4: Comparison of the Amounts of NaCl (mg/kg) Required to Produce Specific Values of Electrical Conductivity in Different Soils.

EC (dS/m)	Amount of additional NaCl (mg/kg)			
	OECD Soil	Clinton	Scotch Creek	Saanichton
2	1,000	0	457	354
4	2,430	240	802	2,750
8	5,290	812	1,490	1,150
12	8,140	1,380	2,180	4,350

Using the derived relationship between nominal concentrations of NaCl and EC in the different soils, it is possible to predict the electrical conductivity that would result from the addition of different quantities of NaCl to the soil (Table 5.5). If the threshold value of 400 mg Cl^-/kg (nominal-EC_{50} value for plant toxicity), for example, were applied to the different soils, the associated electrical conductivity values that could be expected would range from 1.6 (OECD soil) to 7.2 (Clinton soil). On the other hand, 2900 mg Cl^-/kg , the LC_{20}

threshold based on soil invertebrates, translates into electrical conductivity values of between 7.2 and 35, depending on the soil type.

Table 5.5: Predicted Values of Electrical Conductivity for Different Soils in Response to Contamination with NaCl

Nominal concentrations (mg/kg)			Electrical Conductivity dS/m (predicted)			
NaCl	Na^+	Cl^-	OECD	Clinton	Scotch Creek	Saanichton
500	200	300	1.3	5.8	2.7	2.4
700	300	400	1.6	7.2	4.1	2.9
1000	400	600	2.0	9.3	6.1	3.6
2000	800	1200	3.4	16	13	6.1
4000	1600	2400	6.2	30	27	11
4700	1800	2900	7.2	35	31	13
6000	2400	3600	9.0	44	40	16

The importance of soil texture in determining electrical conductivity for a given concentration of salt is well documented in the literature (US Soil Salinity Laboratory). Saturation percentage (the weight of water added to 100 g dry soil to produce a saturated paste) can be used to predict how the soil will respond to the addition of salt (USDA, 1954)

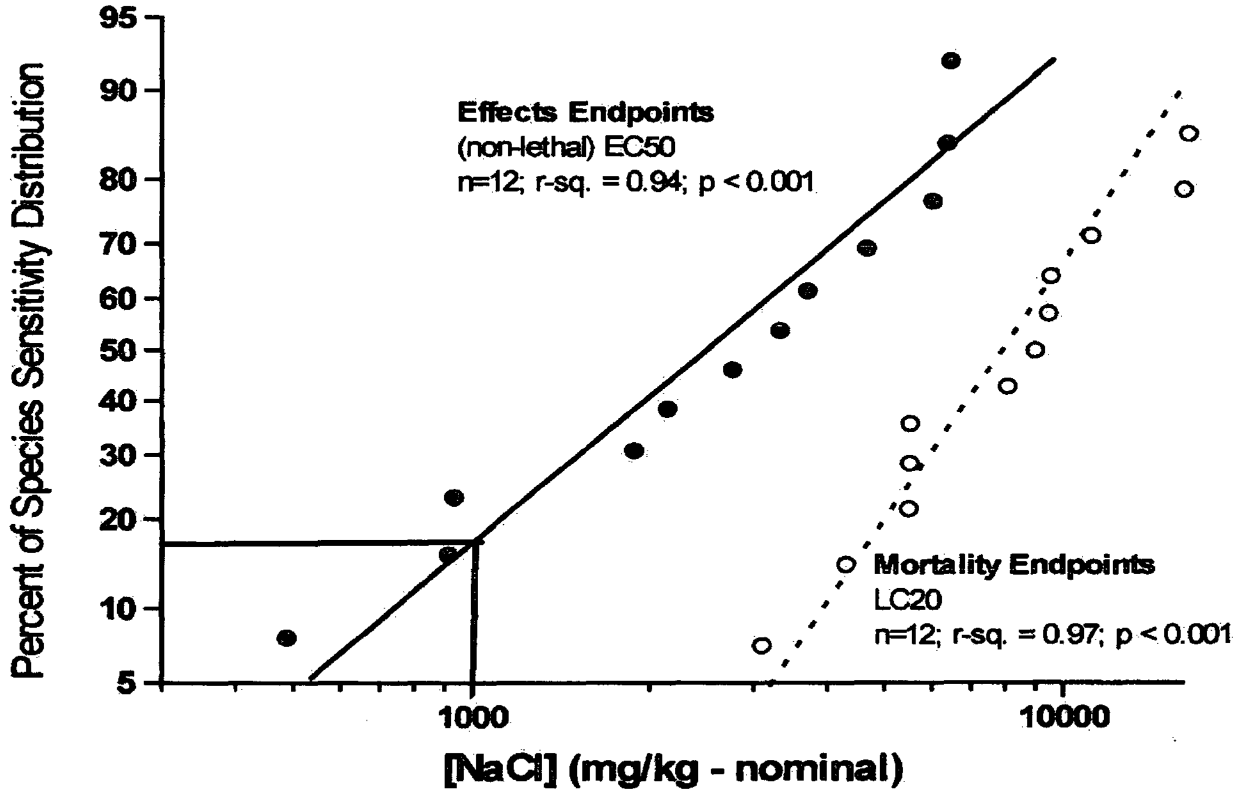

Figure 6.1: Soil Invertebrate Species Sensitivity Distribution to NaCl (mg/kg) Based on Laboratory Toxicity Test Data

Table 6.1 shows the relationship between nominal levels of NaCl in the soil, and the predicted percentage of invertebrate species demonstrating lethal (LC_x) or non-lethal (EC_{50}) effects.

Table 6.1: Relationship Between Percent of Soil invertebrate Species Potentially Affected and Soil NaCl Concentration (Nominal)

Percent of Species Sensitivity Distribution	Predicted Soil Conc. of NaCl (mg/kg soil) Corresponding to Effect Type and Level	
	LC_{20}	EC_{50}
5	3,200	660
10	3,500	770
15	3,900	890
20	4,300	1,000
25	**4,700**	**1,200**
30	5,200	1,400
35	5,700	1,600
40	6,300	1,900
45	6,900	2,200
50	7,600	2,500
55	8,300	2,900
60	9,200	3,400
65	10,000	4,000
70	11,000	4,600
75	12,000	5,300
80	13,000	6,100
85	15,000	7,200
90	16,000	8,300

A review of the literature identified several field studies on the environmental effects of NaCl (Table B-1 *Other supplemental data*). While it is not possible to use these data directly in calculating a thresholds effects concentration, these studies provide evidence that the protective levels suggested above are not unrealistic.

Table 6.4: Summary of Soil Invertebrate Toxicity Thresholds for NaCl in Soil

Ecological Endpoint	Salt or Ion	Concentration in Soil (mg/kg)	Comments
EC_{50} -NL	NaCl	1,200	Nominal concentration
	Cl^-	728	
	Na^+	472	
	Cl^-	**630**	Measured in Saturated Paste
	Na^+	**320**	
LC_x	NaCl	4,700	Nominal concentration
	Cl^-	2,900	
	Na^+	1,800	
	Cl^-	**2,500**	Measured in Saturated Paste
	Na^+	**1,200**	

Figure 6.3, below. In all cases, the concentration reported was the nominal (spiked) soil NaCl concentration. Based on this data, estimates of the number of species potentially affected at various nominal NaCl concentrations are provided in Table 6.6.

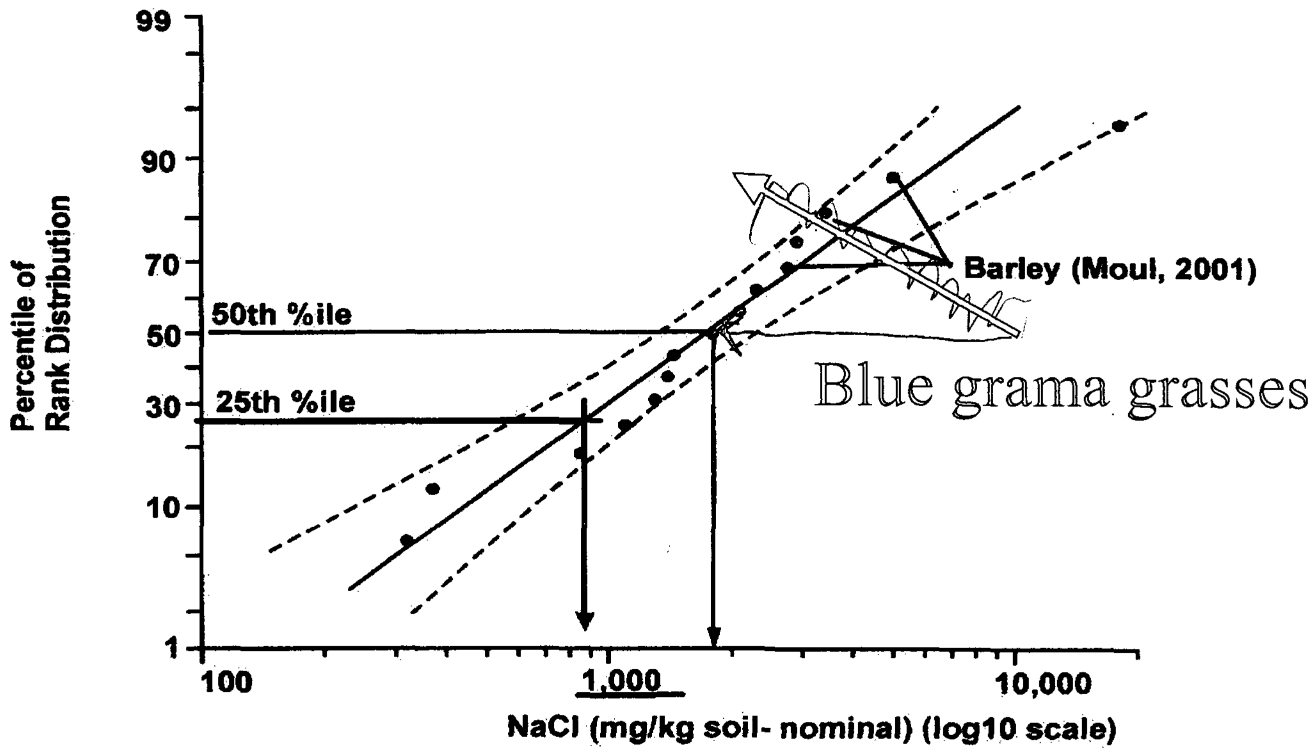

Figure 6.3: Plant Species Sensitivity to NaCl in Soil

Table 6.6: Relationship Between Percent of Plant Species Potentially Affected and Soil NaCl Concentration (Nominal)

Percent of Plant Species Potentially Affected (50% Loss of Yield – EC_{50})		Soil NaCl Concentration (mg/kg nominal)
5		330
10	Scots Pine	400
15	Blue Spruce	480
20		580
25		**700**
30		840
35		1000
40		1200
45		1500
50		1800
55		2200
60		2600
65		3200
70		3800
75		4600
80		5600
85		6700
90		8100

In the absence of more toxicity data for mortality endpoints, the geometric mean of the two available points provides a provisional estimate of NaCl soil thresholds based on plant mortality. The geometric mean of 1,400 mg/kg and 500 mg/kg NaCl is approximately 840 mg/kg NaCl.

Questions?