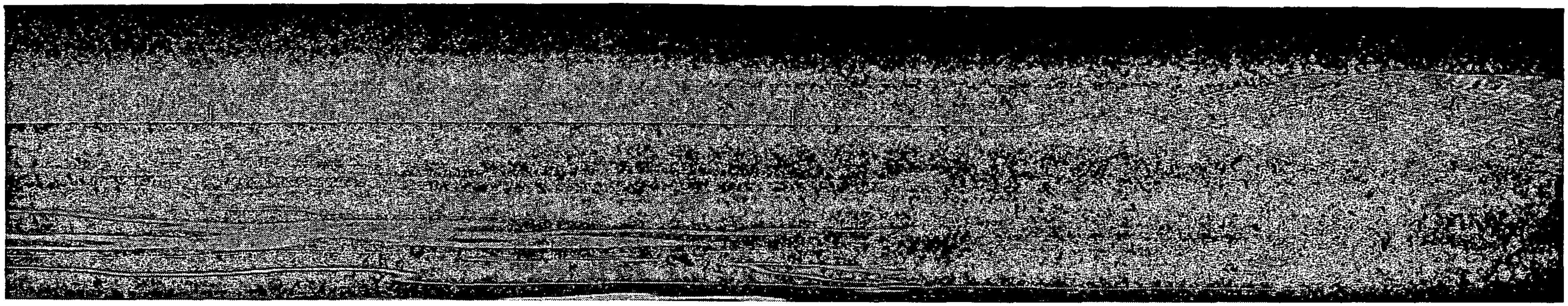


Dr. Daniel B. Stephens

Principal Hydrologist
Daniel B. Stephens & Associates, Inc.
Adjunct Professor of Hydrology, NM Tech
Adjunct Professor of Geology, UNM

Rebuttal testimony in the matter of the application of the New Mexico Oil Conservation Division for repeal of existing rule 50 concerning pit waste management and adoption of new rules governing pit waste management

Case No. 14015

Daniel B. Stephens & Associates, Inc.

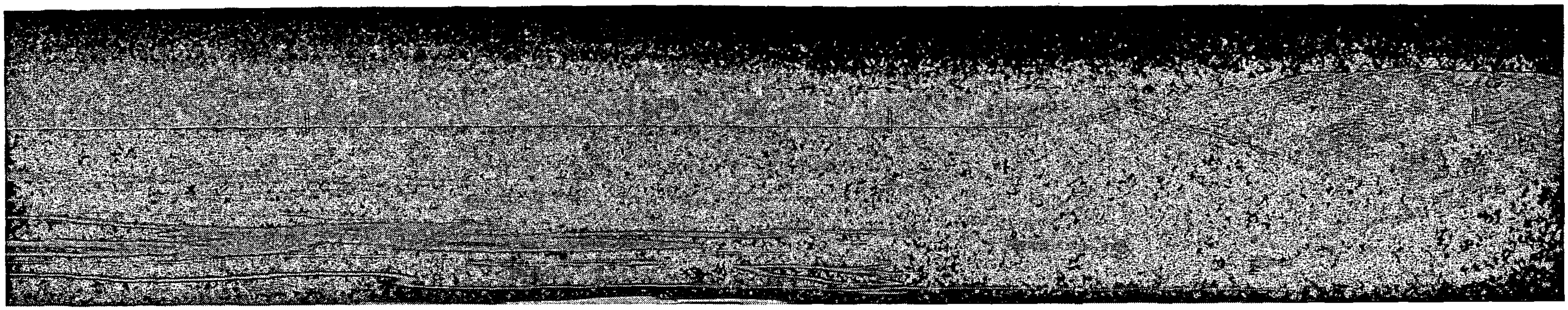
Industry Committee
Rebuttal Exhibit No. 12
12-10-07

Organization

- Part 1. Rebuttal to OCD Analysis
- Part 2. Additional Rebuttal to OCD's critique of DBSA Analysis
- Part 3. Comments on Dr. Neeper's Analysis

Overview Part I

- OCD Analysis Is Unreliable
- Concentration from landfill far outweighs cumulative impact from pits



NMOCD Exhibits 20 and 21

Daniel B. Stephens & Associates, Inc.

Our understanding of NMOCD Dilution Analysis

- NMOCD maximum impact at the bottom of the vadose zone from "good liner" simulation is ~6,000 mg/L

```
VTRNSPThpllgg.doc

CONCENTRATION AT BOTTOM OF VADOSE ZONE
 RUN NO.    1
    AT TIME = 0.6038E+03   CONC = 0.1294E+03
    AT TIME = 0.7996E+03   CONC = -.1557E+03
    AT TIME = 0.9629E+03   CONC = 0.7466E+03
    AT TIME = 0.1099E+04   CONC = 0.2758E+04
    AT TIME = 0.1212E+04   CONC = 0.4459E+04
    AT TIME = 0.1307E+04   CONC = 0.5448E+04
    AT TIME = 0.1385E+04   CONC = 0.5873E+04
    AT TIME = 0.1451E+04   CONC = 0.5956E+04
```

NMOCD Exhibit 20, p. 105

NMOCD Model Outputs Negative Concentrations: Unexplained

Examples from NMOCD Exhibit 20, p. 105

```
VTRNSPThp11gg.doc

CONCENTRATION AT BOTTOM OF VADOSE ZONE
 RUN NO.     1
     AT TIME = 0.6038E+03  CONC = 0.1294E+03
     AT TIME = 0.7996E+03  CONC = -.1557E+03
     AT TIME = 0.9629E+03  CONC = 0.7466E+03
     AT TIME = 0.1099E+04  CONC = 0.2758E+04
     AT TIME = 0.1212E+04  CONC = 0.4459E+04
     AT TIME = 0.1307E+04  CONC = 0.5448E+04
     AT TIME = 0.1385E+04  CONC = 0.5873E+04
     AT TIME = 0.1451E+04  CONC = 0.5956E+04
     AT TIME = 0.1506E+04  CONC = 0.5862E+04
     AT TIME = 0.1551E+04  CONC = 0.5690E+04
     AT TIME = 0.1554E+04  CONC = 0.5679E+04
     AT TIME = 0.1556E+04  CONC = 0.5667E+04
     AT TIME = 0.1559E+04  CONC = 0.5655E+04
     AT TIME = 0.1561E+04  CONC = 0.5643E+04
     AT TIME = 0.1564E+04  CONC = 0.5630E+04
     AT TIME = 0.1566E+04  CONC = 0.5618E+04
     AT TIME = 0.1569E+04  CONC = 0.5605E+04
     AT TIME = 0.1571E+04  CONC = 0.5592E+04
     AT TIME = 0.1574E+04  CONC = 0.5579E+04
     AT TIME = 0.1576E+04  CONC = 0.5566E+04
     AT TIME = 0.1579E+04  CONC = 0.5552E+04
     AT TIME = 0.1581E+04  CONC = 0.5539E+04
     AT TIME = 0.1584E+04  CONC = 0.5525E+04
     AT TIME = 0.1586E+04  CONC = 0.5511E+04
     AT TIME = 0.1589E+04  CONC = 0.5497E+04
     AT TIME = 0.1591E+04  CONC = 0.5482E+04
     AT TIME = 0.1594E+04  CONC = 0.5468E+04
     AT TIME = 0.1596E+04  CONC = 0.5453E+04
     AT TIME = 0.1599E+04  CONC = 0.5438E+04
     AT TIME = 0.1601E+04  CONC = 0.5423E+04
     AT TIME = 0.1647E+04  CONC = 0.5126E+04
     AT TIME = 0.1701E+04  CONC = 0.4722E+04
     AT TIME = 0.1767E+04  CONC = 0.4200E+04
     AT TIME = 0.1846E+04  CONC = 0.3560E+04
     AT TIME = 0.1940E+04  CONC = 0.2826E+04
     AT TIME = 0.2054E+04  CONC = 0.2049E+04
     AT TIME = 0.2190E+04  CONC = 0.1306E+04
     AT TIME = 0.2353E+04  CONC = 0.6831E+03
     AT TIME = 0.2549E+04  CONC = 0.2449E+03
     AT TIME = 0.3348E+04  CONC = -.5026E+02
```

AT TIME = 0.7996E+03 CONC = -.1557E+03

-155.7 mg/L !

AT TIME = 0.3348E+04 CONC = -.5026E+02

-50.26 mg/L !

Daniel B. Stephens & Associates, Inc.

NMOCD Model Creates Chloride Mass

Infiltration rate is 29.8 mm/yr

Duration of pulse is 50 years

PAGE 0086

VARIABLE NAME	UNITS	DISTRIBUTION	PARAMETERS MEAN	STD DEV	LIMITS MIN	MAX
Infiltration rate	m/yr	CONSTANT	0.298E-01	-999.	0.100E-09	0.100E+11
Area of waste disposal unit	m^2	CONSTANT	167.	-999.	0.100E-01	-999.
Duration of pulse	yr	CONSTANT	50.0	-999.	0.100E-08	-999.
Spread of contaminant source	m	DERIVED	-999.	-999.	0.100E-08	0.100E+11
Recharge rate	m/yr	CONSTANT	0.000E+00	-999.	0.000E+00	0.100E+11
Source decay constant	1/yr	CONSTANT	0.000E+00	-999.	0.000E+00	-999.
Initial concentration at landfill	mg/l	CONSTANT	0.100E+06	-999.	0.000E+00	-999.
Length scale of facility	m	DERIVED	-999.	-999.	0.100E-08	0.100E+11
Width scale of facility	m	DERIVED	-999.	-999.	0.100E-08	0.100E+11
Near field dilution		DERIVED	1.00	0.000E+00	0.000E+00	1.00

NMOCD Exhibit 20, p. 86

Pore water concentration is 100,000 mg/L

Daniel B. Stephens & Associates, Inc.

NMOCD Model Creates Chloride Mass: Impossible

- NMOCD model is not mass conservative - it outputs more mass then is in the pit

- MULTIMED leaches chloride from pit for 50 years regardless of mass in pit

- For example:
  - Initial mass in HELP/MULTIMED model for 100,000 mg/L Permian Basin simulation is 40,000 pounds
  - The mass extracted in the corresponding no liner simulation was 55,000 pounds
  - This is a mass balance error of nearly 40% !

NMOCD Model Input Dispersivity Is Incorrect

- Dispersivity describes the degree of contaminant mixing in soil and ground water.
- Equation in MULTIMED manual estimates vadose dispersivity based on vadose zone thickness
- The equation uses **meters**
- Apparently NMOCD used **feet**
- The resulting vadose zone dispersivity is over estimated by 3x in all simulations

Model Input Is Unjustified

- NMOCD aquifer dispersivities in MULTIMED are given as -999. Unexplained.
- Dispersivity is a positive number.

NMOCD Claims 8' Mixing Zone

- NMOCD model output shows mixing zone is 4 inches in every simulation; **Totally Unrealistic**
- NMOCD has not provided support for 8 foot mixing zone thickness
  - MULTIMED user manual was never officially published by EPA. NMOCD has not provided MULTIMED user manual
  - NMOCD has not provided MULTIMED input files or screen shots that support 8 foot mixing thickness

Inconsistent model parameters

- Porosity:
  - MULTIMED (Vadose zone): 25%
  - HELP (Shallow soil): 45-50%

- Residual Water Content input to MULTIMED (11.6%) is likely too large if porosity is only 25%.

Inconsistent model parameters

- Saturated Hydraulic Conductivity (Permeability)
  - MULTIMED: 2.8 ft/day in vadose zone and 0.28 ft/day in aquifer.
  - HELP: 0.5 ft/d to 2.0 ft/day in shallow soil
- Bulk density
  - Input 1.83 g/cc in vadose zone in MULTIMED:
  - Is inconsistent with input porosity of 25%.
  - 1.83 g/cc correlates with 31% porosity
  - 25% porosity correlates with bulk density of 1.99 g/cc
- van Genuchten parameter
  - Input n (1.09) in MULTIMED; typical of silty clay
  - Input Ksat (2.8 ft/d) in MULTIMED is typical of loamy sand.

HELP Modeling: Unjustified Input

- Multiplies Soil Cover Permeability by 2.49 factor
- Leads to:
  - Underestimating runoff
  - Overestimating infiltration
- No justification provided

```
                    LAYER  1
                    --------

         TYPE 1 - VERTICAL PERCOLATION LAYER
            MATERIAL TEXTURE NUMBER   6
THICKNESS                  =     24.00   INCHES
POROSITY                   =     0.4530 VOL/VOL
FIELD CAPACITY             =     0.1900 VOL/VOL
WILTING POINT              =     0.0850 VOL/VOL
INITIAL SOIL WATER CONTENT =     0.1113 VOL/VOL
EFFECTIVE SAT. HYD. COND.  =  0.720000011000E-03 CM/SEC
NOTE:  SATURATED HYDRAULIC CONDUCTIVITY IS MULTIPLIED BY  2.49
       FOR ROOT CHANNELS IN TOP HALF OF EVAPORATIVE ZONE.
```

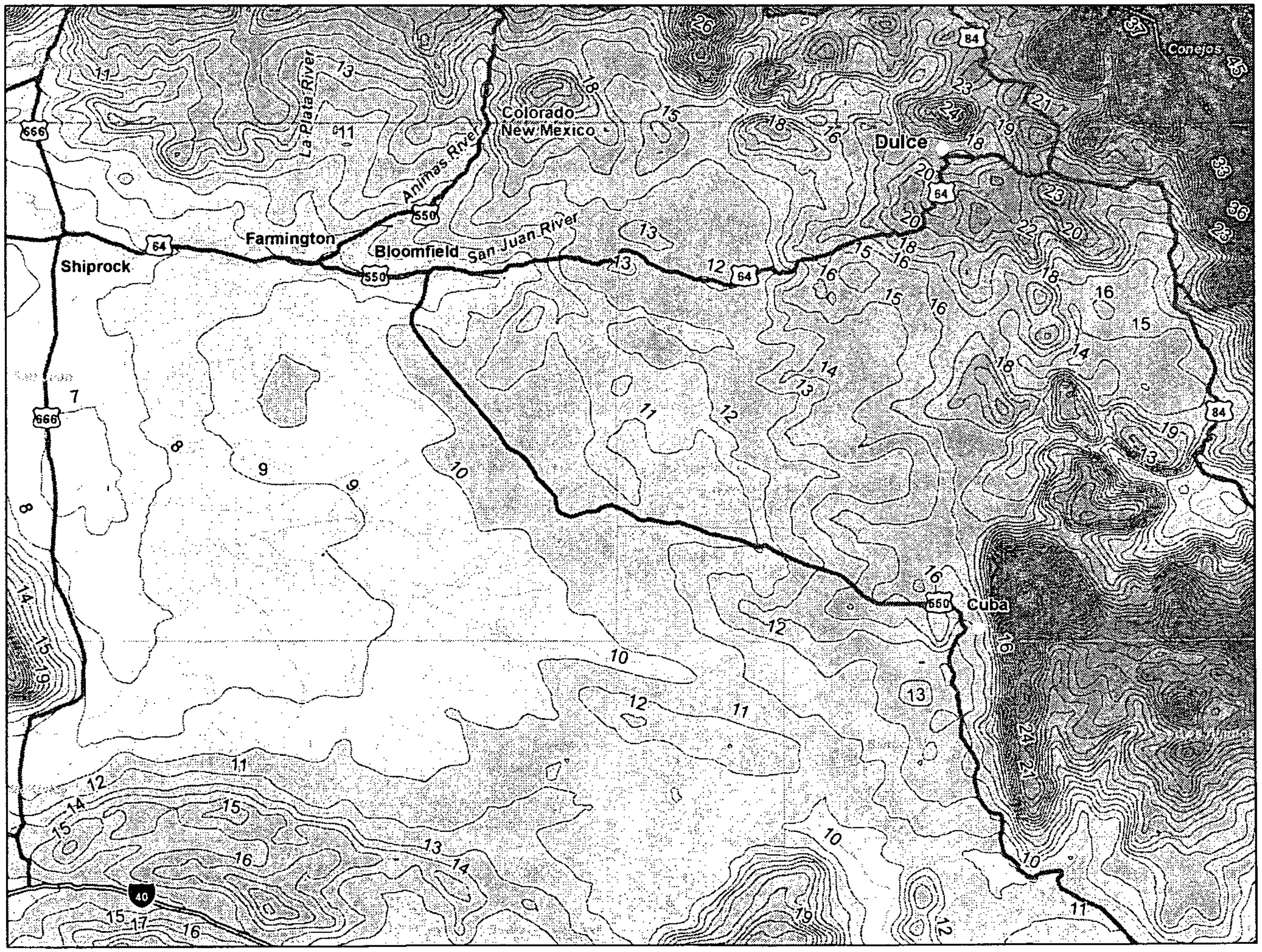
Exhibit 21 - San Juan Basin Precipitation is not Representative

- Dulce has higher average annual precipitation than most of the San Juan basin

HELP Conceptual Model (inputs)

- Two sets of weather data* for 50 years (1951 -2000):
  - Permian Basin (Hobbs at an average precipitation of ~16"/y)
  - San Juan Basin (Dulce at an average precipitation of ~17"/y)

Dulce Precipitation not Representative of San Juan Basin



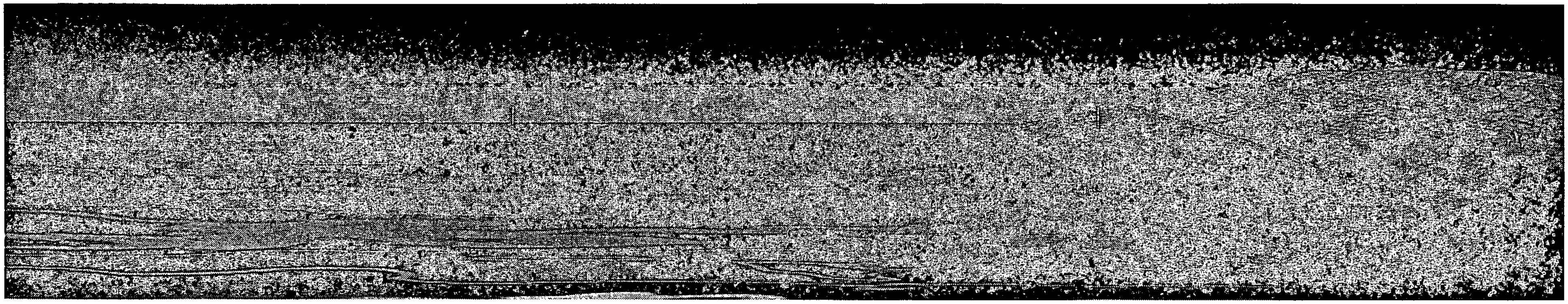
Mean Annual Precipitation (inches) for 1971 - 2000 (PRISM; Daly and others, 1994).

Daniel B. Stephens & Associates, Inc.

16

Precipitation Data Easily Available Online for San Juan Basin

- Free precipitation data available online for entire western United States at Western Regional Climate Center (WRCC): http://www.wrcc.dri.edu/



NMOCD Exhibits 6, 9 and 10

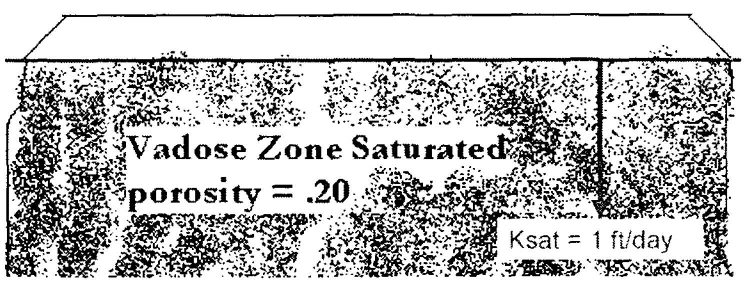
Daniel B. Stephens & Associates, Inc.

Assumptions are Unreasonable

- Assumed (Price ex. 9) leak rate is inconsistent with saturated conditions and 1 ft/day Ksat
- If soil is saturated because of leakage on a pit 150' x 150' in area, and Ksat is 1 ft/day, then water demand would be 4000 bbl/day (116gpm); unreasonably high.

Exhibit 9, p. 4

150'x150'x6' Drilling Pit



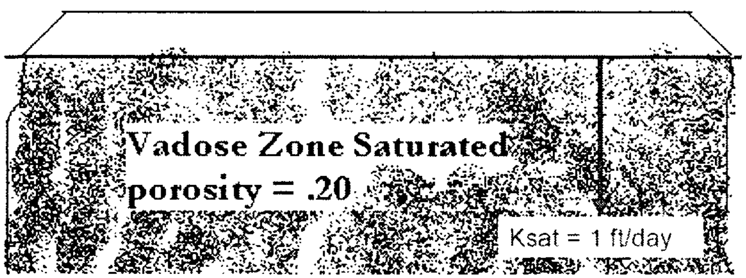
Daniel B. Stephens & Associates, Inc.

Assumptions are Unreasonable

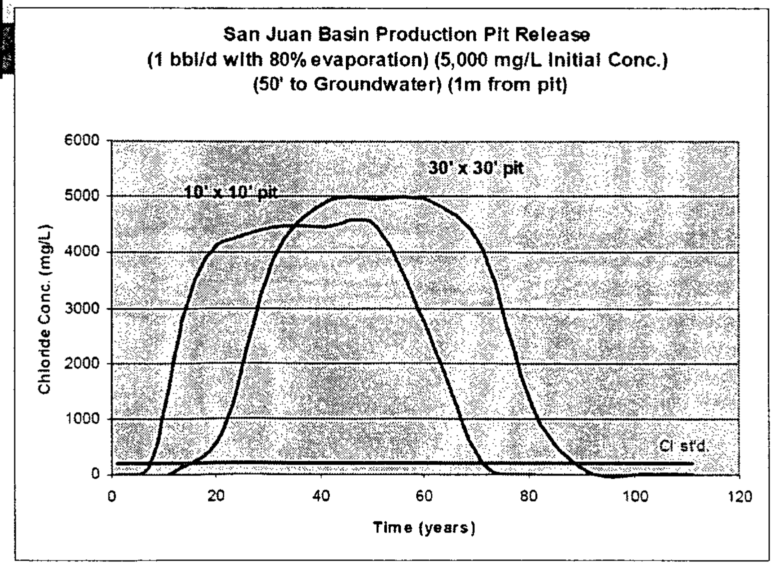
- Assumed leakage at 0.2 bbl/day (0.005 gpm) is inconsistent with saturated conditions for a 30ft x 30 ft size pit (Price ex. 6, p. 19)

Exhibit 9, p. 4

150'x150'x6' Drilling Pit



Modeling Results



Daniel B. Stephens & Associates, Inc.

Exhibit 9 Wetting Front Calculation Error

Time Calculations of Fluid Movement

IF NOT SATURATED, CANNOT USE TOTAL POROSITY

- **Q = K*i*A** **V = (K* I)/η**
- How long would it take for fluid to reach 30 feet in saturated zone with Ksat = 1 ft/day and I = 1?
- V = {[1 ft/day * 1] / 0.2} = 5 ft/day
- V = 5 ft/day
- It would take **6 days** at 0.2% porosity with a conductivity of 1 ft/day to reach 30 feet below the bottom of the pit.
- How long would it take the fluid to reach 20 feet below the 30 feet barrier?
- V = {[0.01 ft/day * 1] / 0.2} = 0.05 ft/day
- V = 0.05 ft/day = 0.6 inch/day = 20 days/foot
- It would take **400 days (1 year and 35 days)** for the fluid to move 20 feet below the 30 feet barrier in an unsaturated zone with a conductivity of 0.01 ft/day and a porosity of 0.2

Daniel B. Stephens & Associates, Inc.

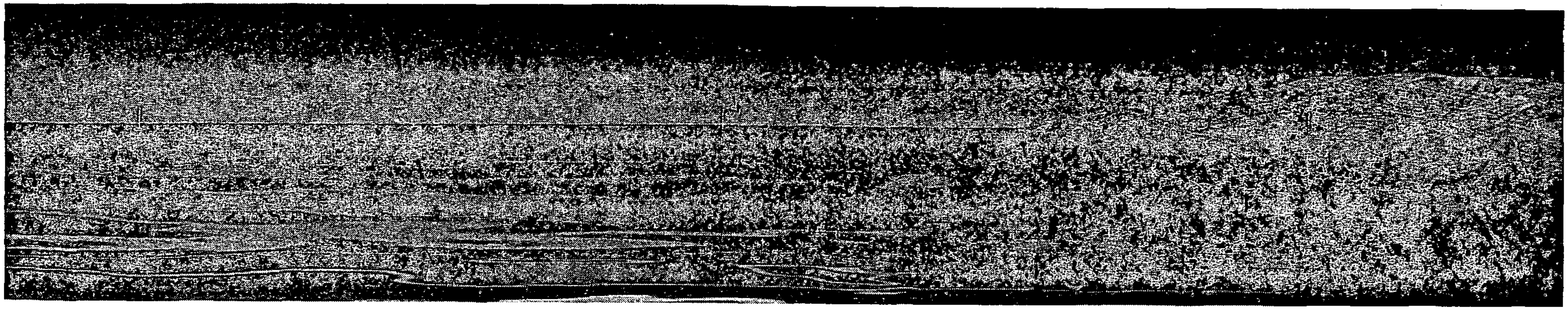
Unrealistic assumptions

Time Calculations of Fluid Movement

6 DAYS OF PONDING REQUIRES 24,000 bbls OF WATER = 116 gpm

- **Q = K*i*A** **V = (K* I)/η**
- How long would it take for fluid to reach 30 feet in saturated zone with Ksat = 1 ft/day and I = 1?
- V = {[1 ft/day * 1] / 0.2} = 5 ft/day
- V = 5 ft/day
- It would take **6 days** at 0.2% porosity with a conductivity of 1 ft/day to reach 30 feet below the bottom of the pit.
- How long would it take the fluid to reach 20 feet below the 30 feet barrier?
- V = {[0.01 ft/day * 1] / 0.2} = 0.05 ft/day
- V = 0.05 ft/day = 0.6 inch/day = 20 days/foot
- It would take **400 days (1 year and 35 days)** for the fluid to move 20 feet below the 30 feet barrier in an unsaturated zone with a conductivity of 0.01 ft/day and a porosity of 0.2

Daniel B. Stephens & Associates, Inc.



Impact of Landfill Exceeds Impact of Multiple Pits

Daniel B. Stephens & Associates, Inc.

Compare Impact of Landfill to Multiple Pits

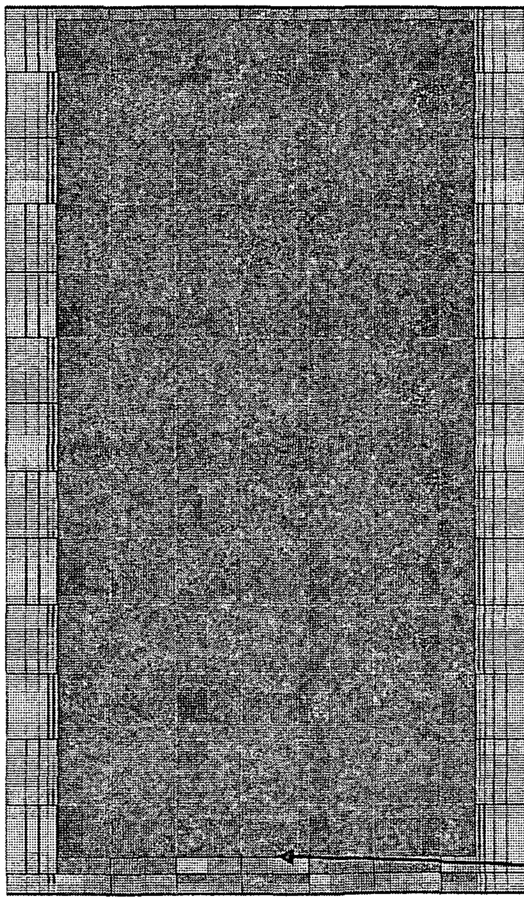
- Landfill
  - Covers an area of 500 acres
  - 50 foot waste zone thickness
- Multiple Pits
  - 50 pits with areas of 0.2 acres (200 ft x 40 ft) spread out every 10 acres over landfill footprint
  - 11 foot waste zone thickness
  - Placed in line to maximize impact

Other Parameters are the Same and Cancel Out in Comparison

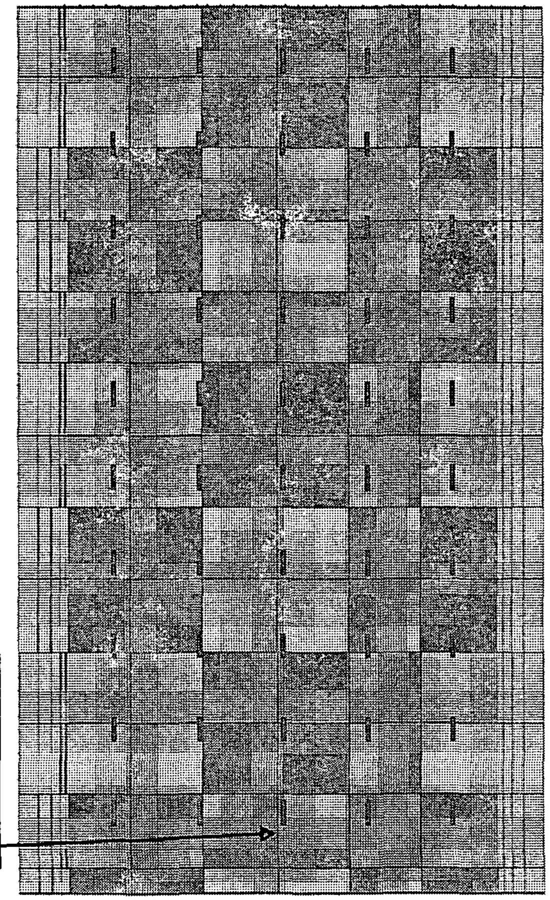
- Setup for both pit and landfill models
  - Steady recharge at 2.5 mm/yr
  - Liners no longer present at start of model simulation 270 years from present
  - Both are fully saturated with water
  - Initial chloride concentration is 1,000 mg/kg in both
  - Aquifer thickness is 50 feet in both
  - Depth to water from base of waste is 50 ft

Model Setup

LANDFILL

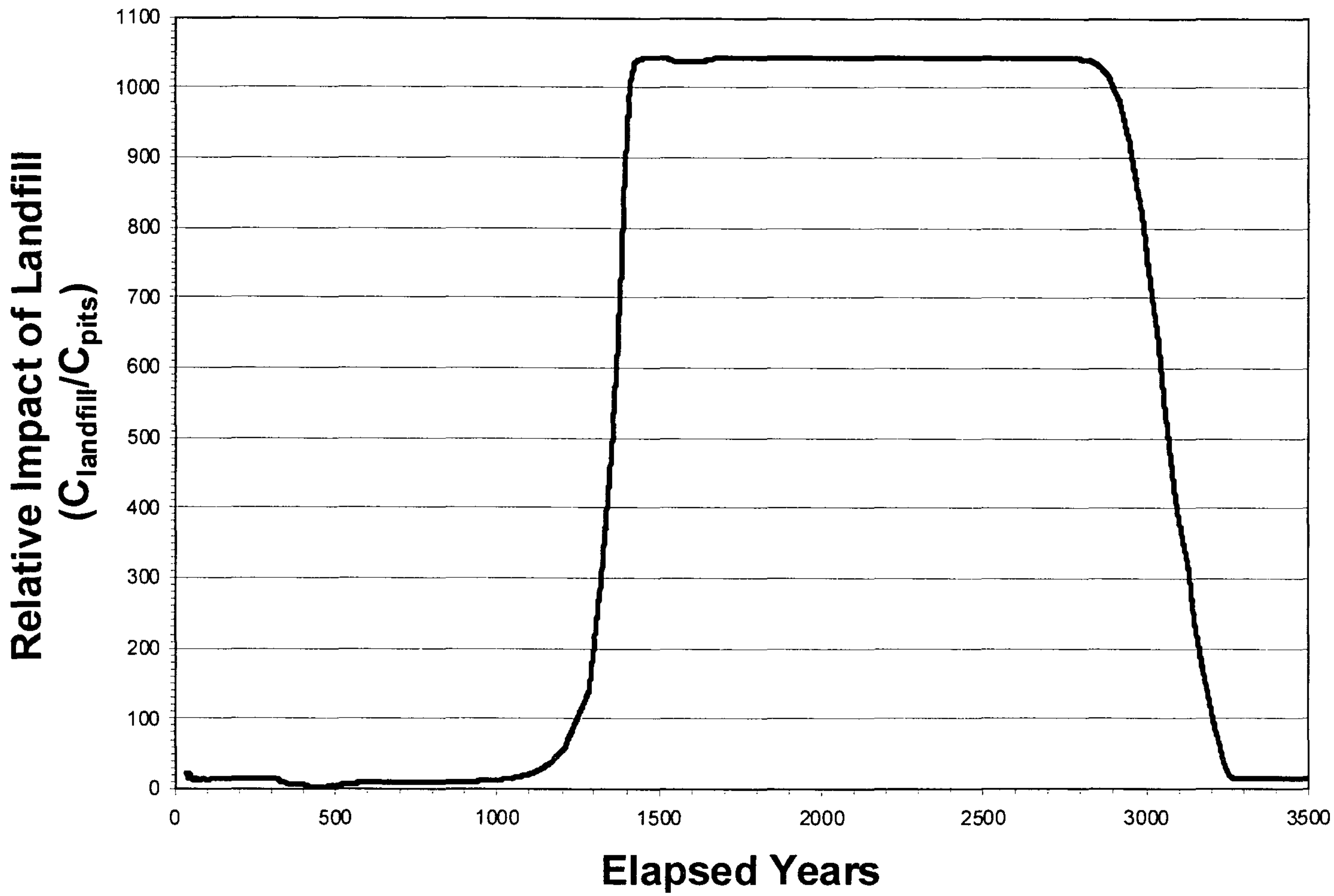


MULTIPLE PITS



Monitor points at maximum impact

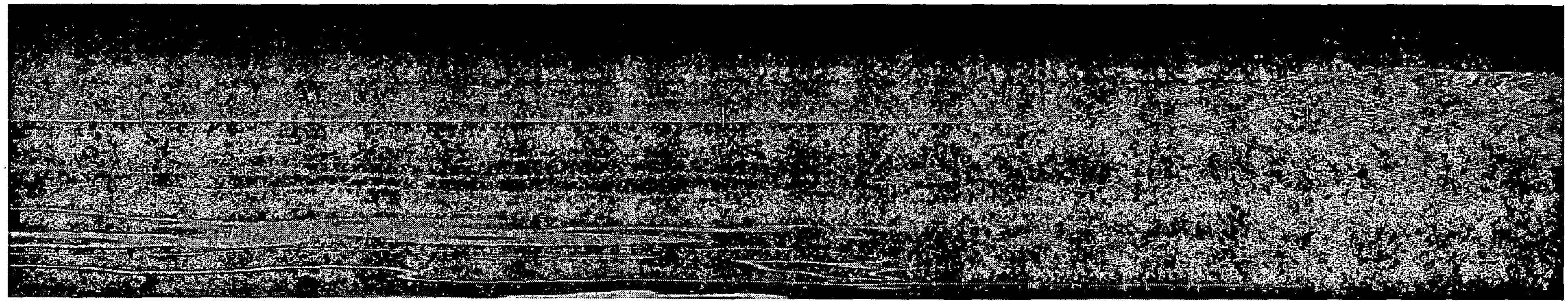
Impact of landfill more than 1000x impact of 50 pits



Daniel B. Stephens & Associates, Inc.

Summary of OCD Critique

- NMOCD model is unreliable
  - creates chloride mass
  - parameters and assumptions are inconsistent
  - 4” mixing zone thickness is unrealistic
  - Dulce, NM precipitation is not representative of northwest, NM
- The impact of landfill far exceeds impact of multiple pits



Part 2. Additional Issues Raised by NMOCD

Our Approach Deals With Treated Waste

	RAW WASTE		TREATED WASTE	
Mixing Ratio	Chloride soil concentration in raw waste (mg/kg)	SPLP chloride result for raw waste (mg/l)	Chloride soil concentration in treated waste (mg/kg)	SPLP chloride result for treated waste (mg/l)
None (100% waste)	24800	1240	24800	1240
1:1 (50% waste : 50% clean soil)	49600	2480	24800	1240
2:1 (33% waste : 66% clean soil)	74400	3720	24800	1240
3:1 (25% waste : 75% clean soil)	99200	4960	24800	1240
4:1 (20% waste : 80% clean soil)	124000	6200	24800	1240

- At 2:1 mix, 3720 mg/L SPLP in Raw Waste =1240 mg/L SPLP Treated Waste

NMOCD Claims 37 mm/yr Recharge is Appropriate Based on my Textbook

- 37 mm/yr is for sparsely vegetated flank of a sand dune

Table 1 Compilation of Diffuse Recharge Analyses in Areas of Low Precipitation

Site	Mean annual precipitation (mm/year)	Potential evapotranspiration (mm/year)	Soil	Recharge (mm/year)	Ref.
1. Socorro, NM	190	1780	Sandy alluvium	4.0–[illegible]	Stephens et al. (1991)
2. Socorro, NM	190	1780	Sandy alluvium	7.0–37	Stephens and Knowlton (1986)
3. Socorro, NM	190	1780	Sandy loam	2–[illegible]	Phillips et al. (1988)
4. Sunland Park, NM	200	1780	Medium sandy alluvium	0.05–1.9	DBS&A (1994)
5. Las Cruces, NM	230	1780	Sandy loam	1.5–9.5	Phillips et al. (1988)
6. Hudspeth County, TX	280	1960	Gravel/clay loam	0.01–1	Scanlon et al. (1991)
7. Curry County, NM	444	1156	Clayey and very fine sand (playa)	2.8	Stone (1986)
8. Curry County, NM	444	1156	Fine to very fine sand (pasture)	0.2	Stone (1986)
9. Curry County, NM	444	1156	Fine sand and caliche (dunes)	1.2	Stone (1986)
10. Hanford, WA	160	1400	Loamy sand, sand	0–100	Gee et al. (1989)
11. Beatty, NV	74	1900	Sand and gravel	0.036	Nichols (1987)
12. South Australia	300	No report	Dune sand	14	Allison et al. (1985)
13. Saudi Arabia	70	2400	Dune sand	20	Dincer et al. (1974)
14. Eastern Botswana	447	1220	Sand, sandstone	0.5–6	Carlsson et al. (1989)
15. Southern Cyprus	390	1450	Fine sand	10–94	Kitching et al. (1980)
16. Central Sudan	225	No report	Sandstone	0.2–1.3	Darling et al. (1992)
17. Northeast Sudan	220	No report	Sandstone	<1	Darling et al. (1992)

From Stephens, 1994. With permission.

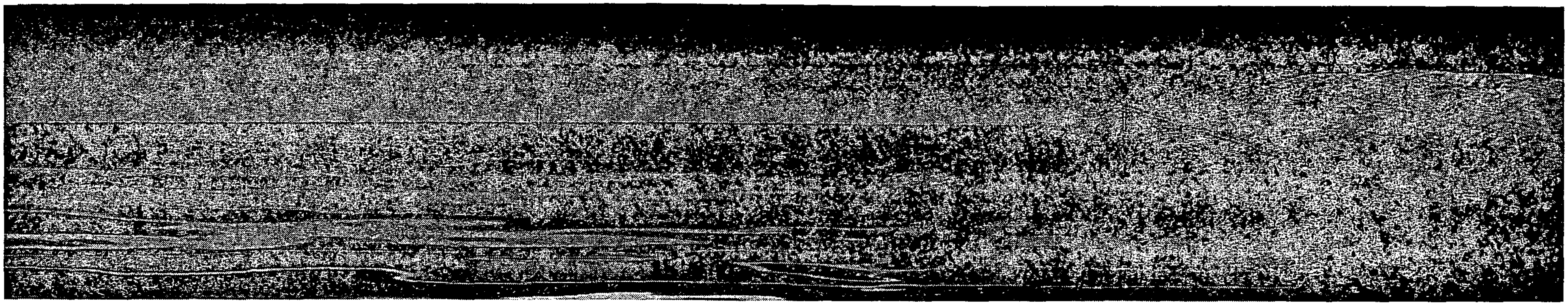
Daniel B. Stephens & Associates, Inc.

Neither NMOCD or IC Approaches Account for a Head of Water

- Both MULTIMED and VADSAT use constant recharge rates that do not account for head of water in pit

- HELP also does not account for head of water in computing recharge.

Daniel B. Stephens & Associates, Inc.



Rebuttal to NMCCA&W Presentation by Dr. Neeper

Daniel B. Stephens & Associates, Inc.

Travel Time Does Not Give Impact

HOW REALISTIC IS THIS MODEL?

The model provides the size and time scales of activity-- how much, how far, how fast. It does not provide exact quantitative estimates, which are sensitive to the numerical values of parameters (e.g. permeability).

NMCCA&W Ex. 3 p. 44

- Travel times are not related to groundwater impact. The greatest impact may be from the slowest travel times or vice versa.

Daniel B. Stephens & Associates, Inc.

Dispersion decreases impact

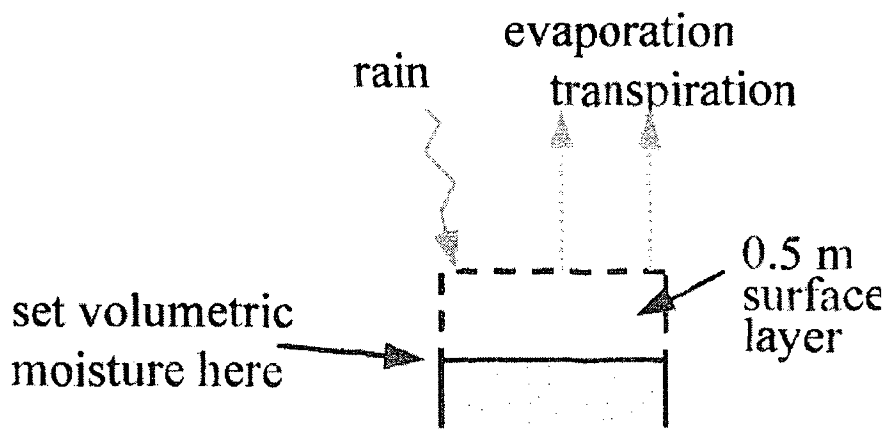
HOW REALISTIC ...?

Three-dimensional dispersion from a pit would allow chloride to move horizontally, creating a broader, initially faster plume, less impeded by the assumed low permeability of the pit material.

NMCCA&W Ex. 3 p. 44

- Considering 3D dispersion will diminish predicted concentrations in impacted soil and groundwater

Thin root zone overestimates recharge



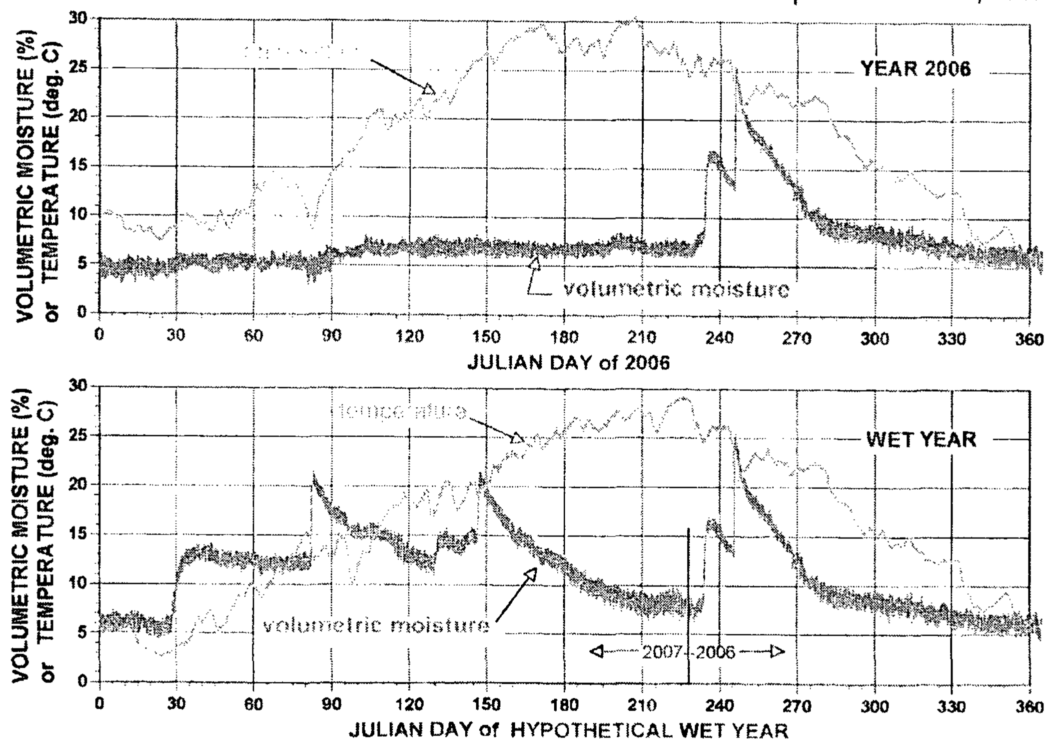
NMCCA&W Ex. 3 p. 32

- Water removed over entire root zone (3 to 10 foot depth)
- Soil likely continues to dry below 50cm
- Dr. Neeper keeps soil too wet; exaggerates recharge

Cannot Assign Same Water Content to Different Soils

- The water content is tied to the soil type where it was measured

NMCCA&W Ex 3 pg.35



Data from: Natural Resources Conservation Service, Pedon 2107, Crossroads, NM

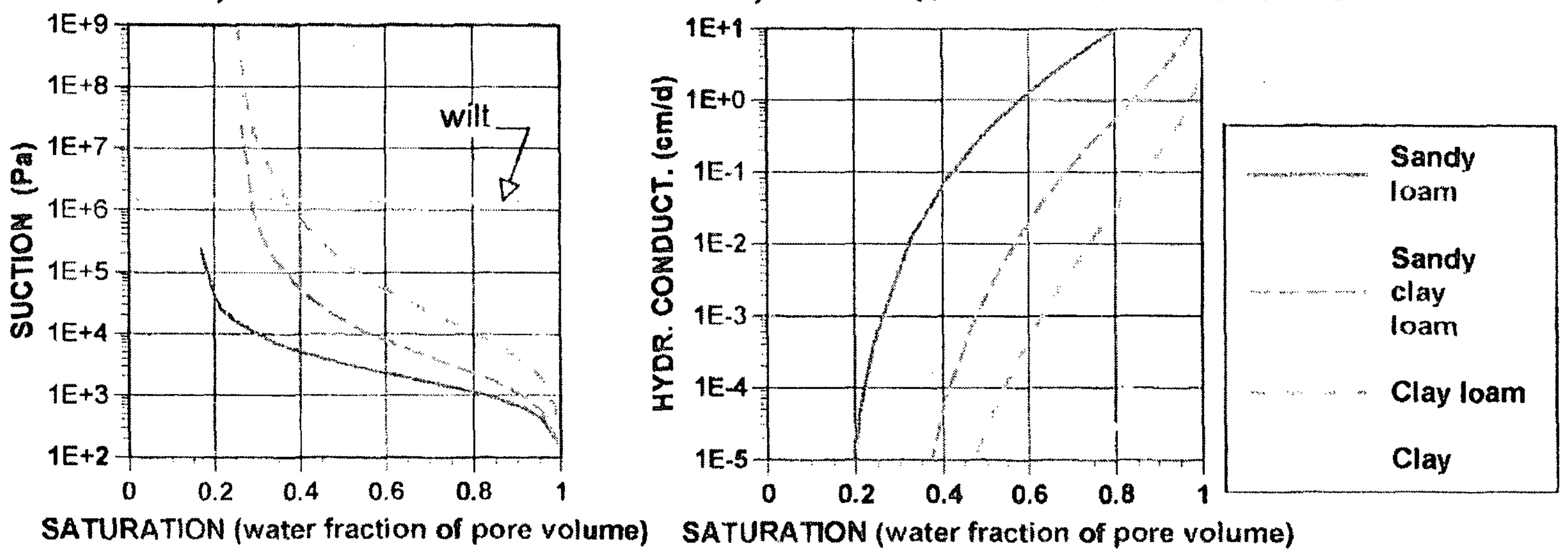
Daniel B. Stephens & Associates, Inc.

Cannot Assign Same Water Content to Different Soils

- Same water content represents widely different hydraulic conductivities and heads

NMCCA&W Ex.3 pg.34

SUCTION, HYDRAULIC CONDUCTIVITY, AND EQUILIBRIUM SATURATION



Daniel B. Stephens & Associates, Inc.

Natural Chloride Concentrations in the Southwest Exceed "Severe" Level

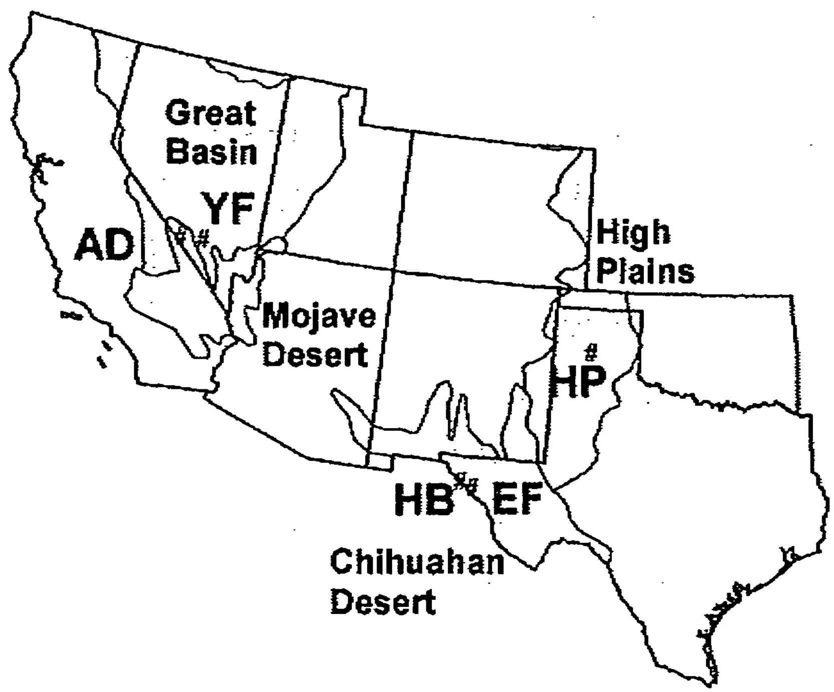
NMCCA&W Ex.3 pg.19

INTERPRETIVE GUIDELINES FOR IRRIGATION WATER ANALYSIS

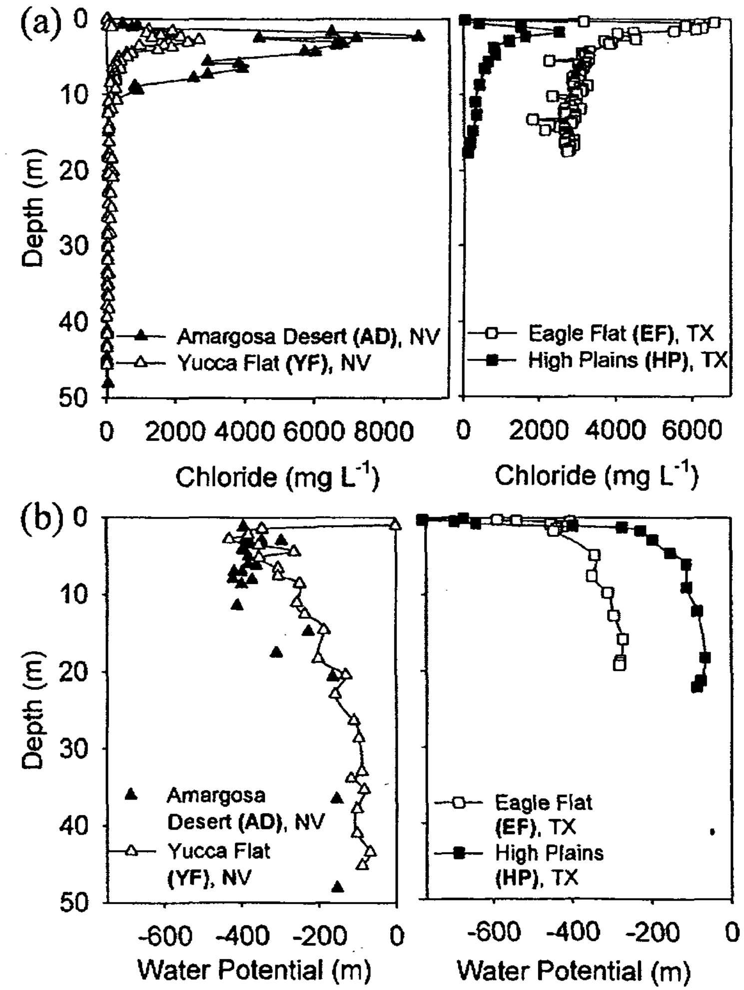
Parameter	Units	Potential Problems		
		None	Increasing	Severe
Sodium (Na)	mg/l	< 70	71 - 180	> 180
Chloride (Cl)	mg/l	< 70	71 - 300	> 300

Daniel B. Stephens & Associates, Inc.

Natural Soil Chloride 'Bulges'



Source: Walvoord & Scanlon, 2004



Daniel B. Stephens & Associates, Inc.

Summary of Points

- Travel times are not related to groundwater impact. The greatest impact may be from the slowest travel times or vice versa
- Considering 3D dispersion will diminish impact
- Measured water content can only be used for soil type where measured

Summary of Points

- Thin root zone causes overestimate of recharge
- Desert vegetation typical extracts water to very low pressures - up to 60 bar (6 MPa)
- High natural salt concentrations, exceed recommended agricultural water concentrations, yet support native vegetation