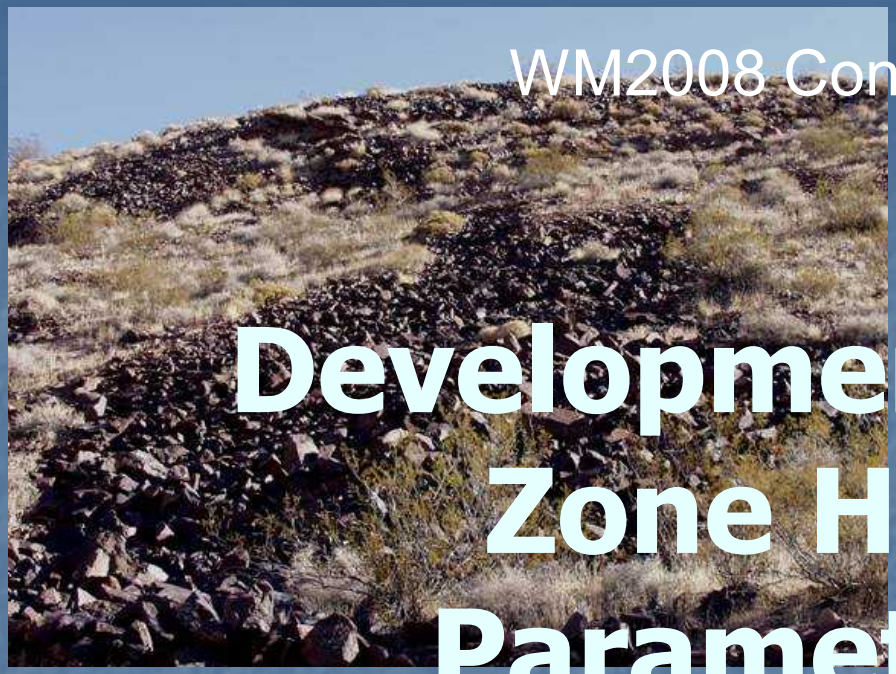
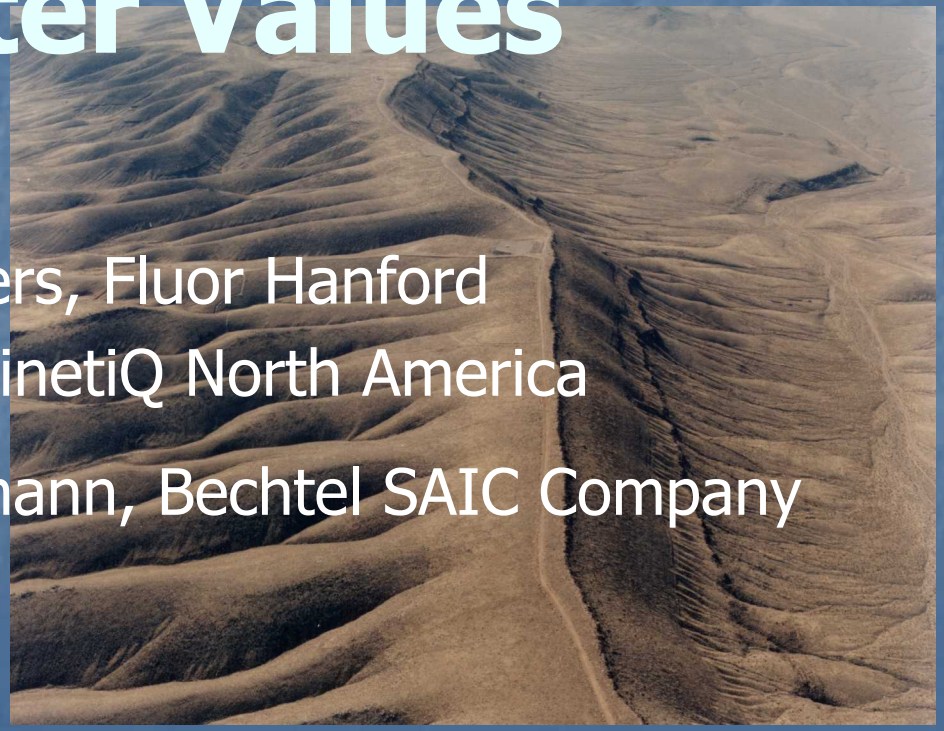


WM2008 Conference, Phoenix, AZ SAND2008-0887P

Development of Vadose-Zone Hydraulic-Parameter Values

Phillip M. Rogers, Fluor Hanford
Zane P. Walton, QinetiQ North America
Gerald H. Nieder-Westermann, Bechtel SAIC Company



INTRODUCTION

- Pedotransfer Function Approach
  - Limited Soil Hydraulic Parameters Data
  - Available Soil Physical Properties Data
- Yucca Mountain Infiltration Model
  - Saturated Hydraulic Conductivity (K_{sat})
  - Field Capacity (Soil-Moisture Content at -0.33 bar)
  - Permanent Wilting Point (Soil-Moisture Content at -60 bar)
  - Soil Saturation (θ_s), estimate of porosity

PARAMETRIC PEDOTRANSFER FUNCTIONS

- Carsel and Parrish (1988)
  - Rawls and Brakensiek (1985), Multiple Regression Model
  - Joint multivariate-density function developed for USDA textural classes based on soil samples from 42 states:

$$\ln(K_{sat}),\ \theta_r,\ \ln(\alpha^{-1}),\ \ln(n-1) =$$
$$[c_0 + c_1S + c_2C + c_3\theta_s + c_{11}S^2 + c_{22}C^2 + c_{33}\theta_s^2 + c_{12}S\%C + c_{13}S\theta_s + c_{23}C\theta_s + c_{112}S^2C + c_{223}C^2\theta_s + c_{113}S^2\theta_s + c_{122}SC^2 + c_{233}C\theta_s^2 + c_{1133}S^2\theta_s^2 + c_{2233}C^2\theta_s^2]$$

PARAMETRIC PEDOTRANSFER FUNCTIONS

Where:

K_{sat} = Saturated hydraulic conductivity (cm/h)

θ_r = Residual water content (cm3/cm3)

α = Empirical van Genuchten et al. (1991) curve fitting constant (1/cm)

n = Empirical van Genuchten et al. (1991) curve fitting constant (unitless)

c = Regression coefficients

S = Percent sand, by weight ($5<S<70$)

C = Percent clay, by weight ($5<C<60$)

θ_s = Total saturated water content (cm3/cm3)

PARAMETRIC PEDOTRANSFER FUNCTIONS

- ROSETTA (Schaap et al. 2001)
  - Neural network-based model
  - Samples obtained from agricultural and nonagricultural soils in temperate-climates zones of the northern hemisphere
    - 2,134 samples for water retention
    - 1,306 samples for K_{sat}
    - 235 samples for unsaturated K

PARAMETRIC PEDOTRANSFER FUNCTIONS

- Advantages:
  - Ease of use and highly respected developers
- Disadvantages:
  - Primarily based on agricultural soils and soils in non-desert climates
  - USGS found that ROSETTA results leads to unreasonably high recharge estimates caused by the over prediction of K_{sat} at Glassboro Study Area, New Jersey (USGS 2003)

NONPARAMETRIC PEDOTRANSFER FUNCTION APPROACH

- Organization of Yucca Mountain Soil Units

Calculated Areas and Deposition Type for Each Soil Unit.			
Soil Unit, (Type of Deposit)	Soil Taxonomic Name	Number of 30 × 30 m Model Cells	Calculated Area (%)
1 (Fluvial)	Typic Argidurids	19,900	7.85
2 (Fluvial)	Typic Haplicalcids	44,065	17.38
3 (Fluvial)	Typic Haplocambids	33,115	13.06
4 (Fluvial)	Typic Torriothents	4,630	1.83
5 (Colluvium)	Lithic Haplocambids	116,813	46.06
6 (Eolian)	Typic Torripsamments	12,205	4.81
7 (Colluvium)	Lithic Haplargids	3,154	1.24
8 (Bedrock)	Rock	795	0.31
9 (Colluvium)	Typic Calciargids	16,441	6.48
10 (Disturbed)	Disturbed Ground	2,479	0.98

NONPARAMETRIC PEDOTRANSFER FUNCTION APPROACH

- Hanford, WA Soils Properties Database
  - Variability and Scaling of Hydraulic Properties for 200 Area Soils, Hanford Site (Khaleel and Freeman, 1995)
- Soil Texture Data
  - % Sand, % Silt, and % Clay
- Hydraulic parameter values from laboratory measurements
  - K_{sat}, θ_r, and θ_s
  - Moisture-retention curve fitting parameters, α and n

NONPARAMETRIC PEDOTRANSFER FUNCTION APPROACH

- Soil Matching Method
  - Match Hanford Site soil texture data with YMP data
- Euclidean distance (D_e), non-subjective measure of "goodness of match"

$$D_e\ (3D) = [(Sand_{ymp} - Sand_{Hanford})^2 + (Silt_{ymp} - Silt_{Hanford})^2 + (Clay_{ymp} - Clay_{Hanford})^2]^{1/2}$$

NONPARAMETRIC PEDOTRANSFER FUNCTION APPROACH

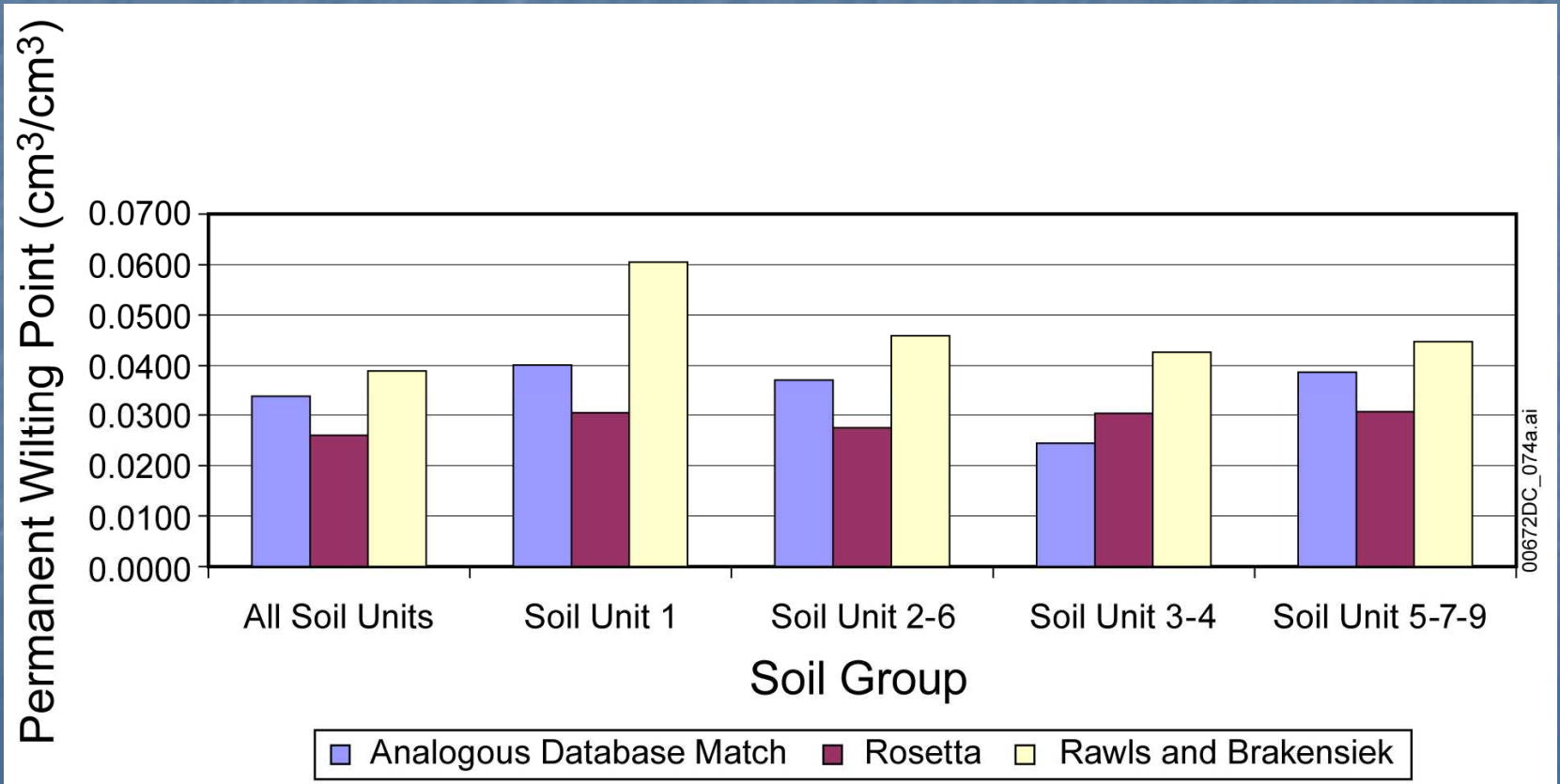
- Analogous parameters for YMP
  - K_{sat}, θ_r, and θ_s
  - Moisture-retention curve fitting parameters, α and n
  - Correct parameters for gravel content
- Develop Moisture retention curves
- Output:
  - K_{sat}, FC (-0.33 bar), PWP (-60 bar), & θ_s

CORROBORATION OF THE MATCHING APPROACH

- Carsel and Parish (Rawls and Brakensiek) and ROSETTA
  - MC at -0.33 bar (-336.6 cm), FC
  - MC at -60 bar (-61,200 cm), PWP
  - K_{sat}
- Nye County, NV data (USDA, National Resource Conservation Service)
  - MC at -0.10 bar (-102 cm)
  - MC at -0.33 bar (- 336.6 cm)

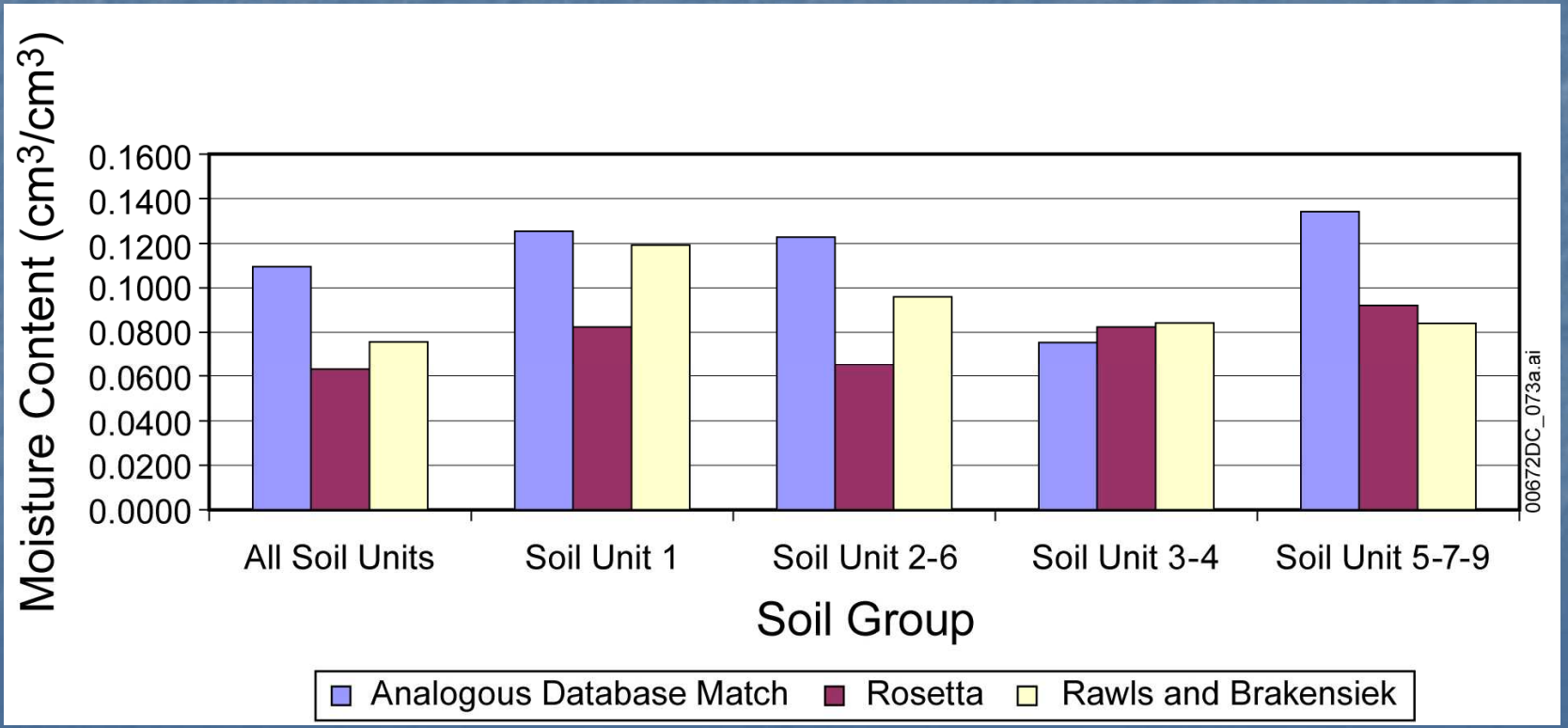
CORROBORATION OF MATCHING APPROACH

Mean permanent wilting point at -60 bar (-61,200 cm) for three pedotransfer function methods using Yucca Mountain data



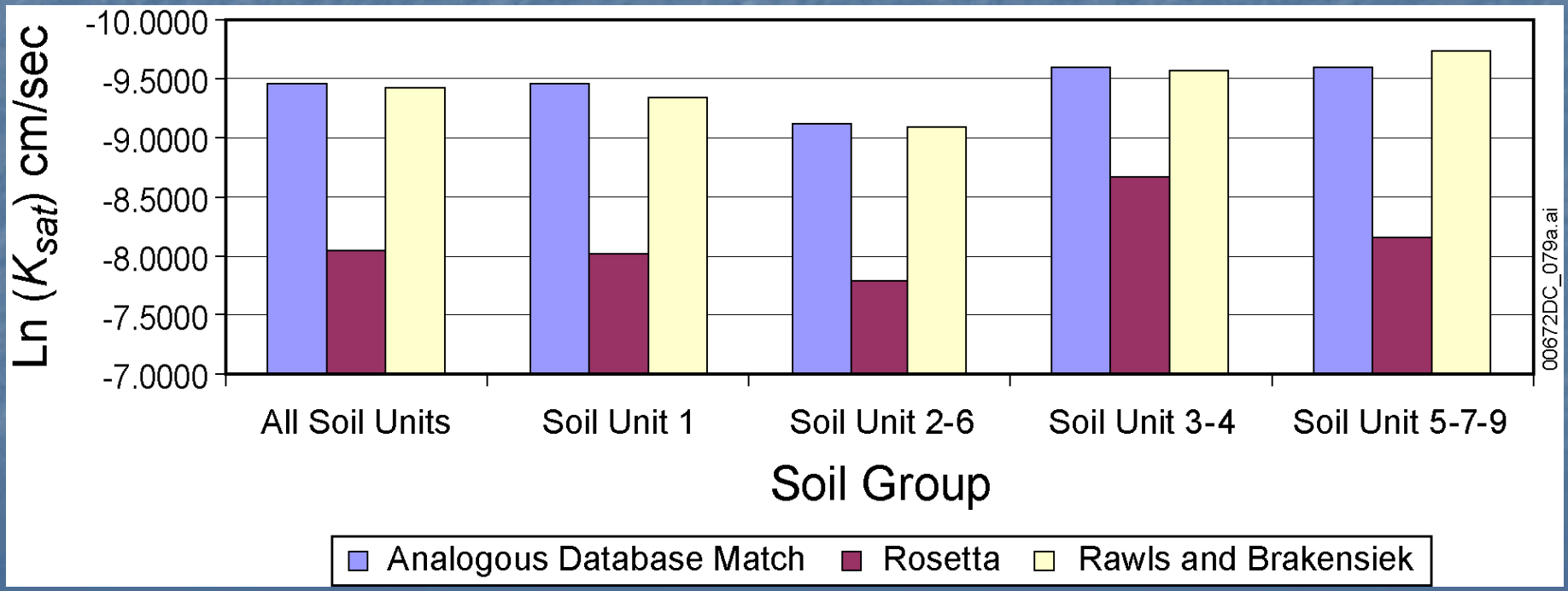
CORROBORATION OF MATCHING APPROACH

Mean moisture content values at -0.33 bar (-336.6 cm) for three pedotransfer function methods using Yucca Mountain data



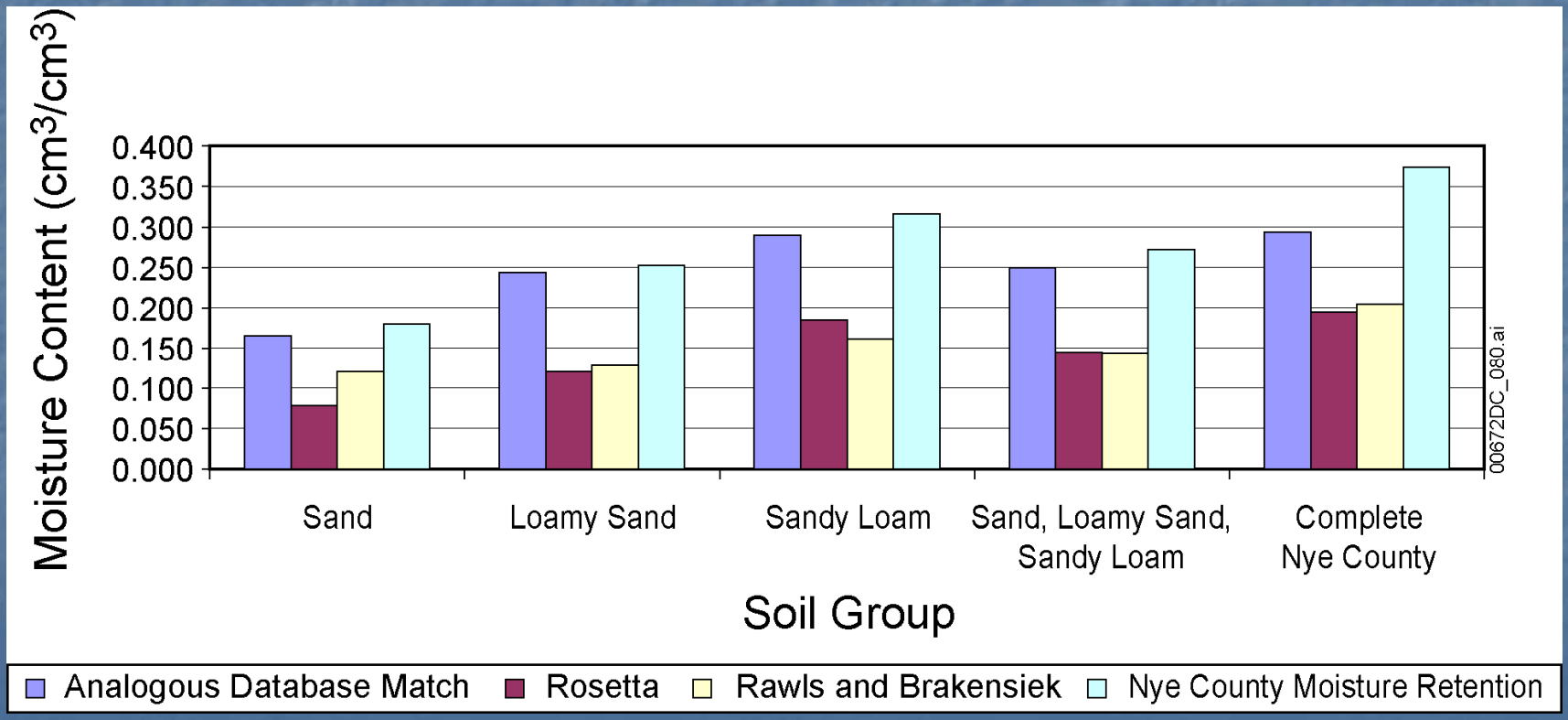
CORROBORATION OF MATCHING APPROACH

Mean ln (K_{sat}) for three pedotransfer function methods using Yucca Mountain data



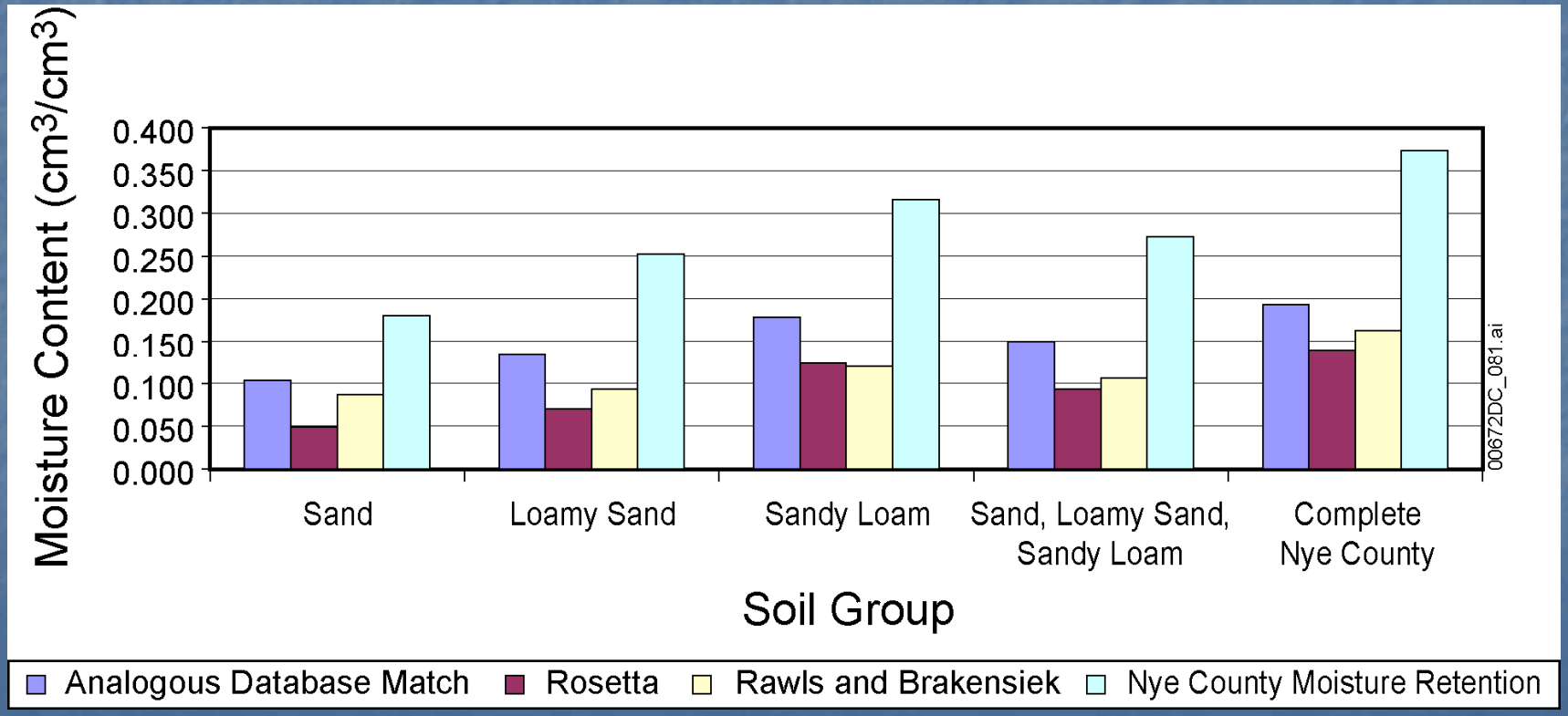
CORROBORATION OF MATCHING APPROACH

Mean moisture content values at –0.10 bar (–102 cm) for three pedotransfer function methods using Nye County data and measured moisture-retention data from Nye County, NV



CORROBORATION OF MATCHING APPROACH

Mean moisture content values at –0.33 bar (–336.6 cm) for three pedotransfer function methods using Nye County data and measured moisture-retention data from Nye County, NV



CONCLUSIONS

- Reasonable estimate of hydraulic parameters when compared with parameteric pedotransfer functions and Nye County, NV soil moisture data
- Good agreement with moisture content data from Nye County, NV
  - Particularly at wet end of moisture retention curve
- Carsel and Parish ROSETTA under-predict MC when compared with Nye, County, NV data

CONCLUSIONS

- Results consistent with USGS findings concerning over prediction of K_{sat} by ROSETTA
- Analogous matching method particularly relevant to CERCLA/RCRA site investigations at Hanford, WA.
  - Estimates of soil hydraulic parameters sparse because of radiological health exposure risks