Adjusting Hydrologic Soil Groups for Post-Construction Conditions and Their Effects on Hydrology Calculations

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Overview of Presentation

- NRCS guidance for curve numbers and urban hydrology (incl. urban soils)
- Soil profile modification during land conversion
- Ohio adjustment to HSG (and CN) for urban soils

NRCS Curve Number Guidance

- National Engineering Handbook, Part 630 Hydrology
  - Chapter 10 – Estimation of Direct Runoff from Storm Rainfall (July 2004)
  - Chapter 9 – Hydrologic Soil-Cover Complexes (July 2004)
  - Chapter 7 – Hydrologic Soil Groups (January 2009)

United States
Department of
Agriculture

**Natural
Resources
Conservation
Service**

Part 630 Hydrology
National Engineering Handbook

NRCS Curve Number Guidance

- National Engineering Handbook, Part 630 Hydrology
  - Chapter 7 – Hydrologic Soil Groups (January 2009)

United States
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Agriculture

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Chapter 7 **Hydrologic Soil Groups**

Hydrologic Soil Group (HSG)

- Hydrologic Soil Group for a limited group of soils was assigned based on measured rainfall, runoff, and infiltrometer data.
- State and NRCS soil scientists assigned HSG for all other (i.e., non-measured) soils based on:
  - Soil properties (texture, structure)
  - Intake and transmission of water
  - Depth to restrictive layer
  - Depth to water table

NRCS. 2009. Hydrologic Soil Groups. Ch. 7, NEH 630 – Hydrology.

Hydrologic Soil Group (HSG)

- The procedure for assigning HSG was more explicitly defined in May 2007 revision to NEH 630, Chapter 7 – Hydrologic Soil Groups.

Table 7–2 Criteria for assignment of hydrologic soil groups when any water impermeable layer exists at a depth greater than 100 centimeters [40 inches]

Soil property	Hydrologic soil group A	Hydrologic soil group B	Hydrologic soil group C	Hydrologic soil group D
Saturated hydraulic conductivity of the least transmissive layer	>10 μm/s (>1.42 in/h)	≤10.0 to >4.0 μm/s (≤1.42 to >57 in/h)	≤4.0 to >0.40 μm/s (≤0.57 to >0.06 in/h)	≤0.40 μm/s (≤0.06 in/h)
	and	and	and	and/or
Depth to water impermeable layer	>100 cm [>40 in]	>100 cm [>40 in]	>100 cm [>40 in]	>100 cm [>40 in]
	and	and	and	and/or
Depth to high water table	>100 cm [>40 in]	>100 cm [>40 in]	>100 cm [>40 in]	>100 cm [>40 in]

NRCS. 2007. Hydrologic Soil Groups. Ch. 7, NEH 630 – Hydrology.

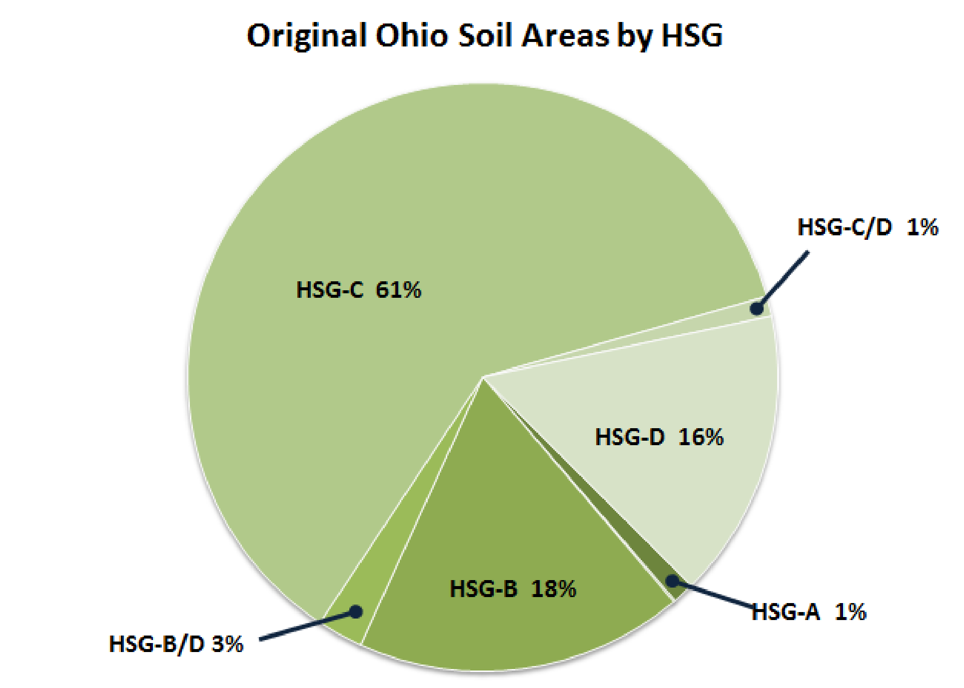
Hydrologic Soil Group (HSG)

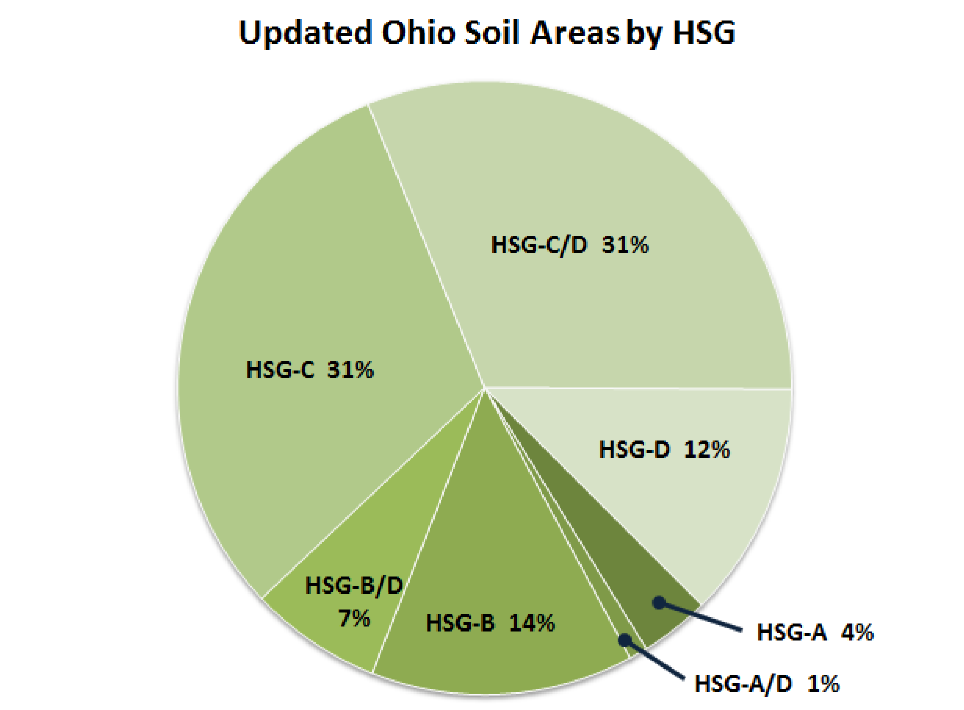
- The procedure for assigning HSG was more explicitly defined in May 2007 revision to NEH 630, Chapter 7 – Hydrologic Soil Groups.
- NRCS turned update of HSGs over to state NRCS offices.
- HSGs for Ohio soils were updated by Ohio NRCS staff in 2008 based on new protocol.
- Updated Ohio HSGs submitted to national NRCS office, incorporated in the national soils database and are now available through Web Soil Survey.

NRCS. 2007. Hydrologic Soil Groups. Ch. 7, NEH 630 – Hydrology.

Hydrologic Soil Group (HSG)

HSG	Original	Updated
	%	%
A	1.2	3.7
A/D	0.1	1.0
B	18.0	13.8
B/D	2.5	7.0
C	61.2	30.8
C/D	1.1	31.3
D	15.8	12.4





Hydrologic Soil Group (HSG)

- NEH 630, Chapter 7 – Hydrologic Soil Groups was revised again in January 2009.

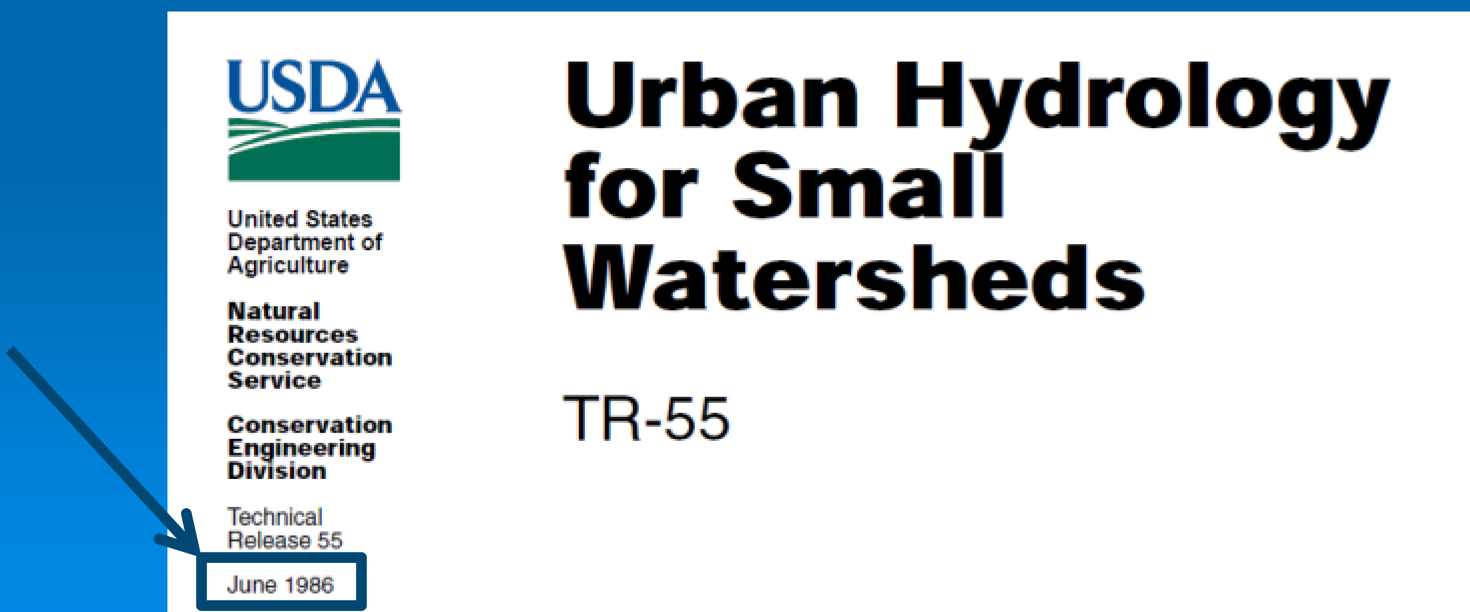
Table 7–1 Criteria for assignment of hydrologic soil group (HSG)

Depth to water impermeable layer [1]	Depth to high water table [2]	K_{sat} of least transmissive layer in depth range	K_{sat} depth range	HSG [3]
<50 cm [<20 in]	—	—	—	D
50 to 100 cm [20 to 40 in]	<60 cm [<24 in]	>40.0 μm/s (>5.67 in/h)	0 to 60 cm [0 to 24 in]	A/D
		>10.0 to ≤40.0 μm/s (>1.42 to ≤5.67 in/h)	0 to 60 cm [0 to 24 in]	B/D
		>1.0 to ≤10.0 μm/s (>0.14 to ≤1.42 in/h)	0 to 60 cm [0 to 24 in]	C/D
		≤1.0 μm/s (≤0.14 in/h)	0 to 60 cm [0 to 24 in]	D
	≥60 cm [≥24 in]	>40.0 μm/s (>5.67 in/h)	0 to 50 cm [0 to 20 in]	A
		>10.0 to ≤40.0 μm/s (>1.42 to ≤5.67 in/h)	0 to 50 cm [0 to 20 in]	B
		>1.0 to ≤10.0 μm/s (>0.14 to ≤1.42 in/h)	0 to 50 cm [0 to 20 in]	C
		≤1.0 μm/s (≤0.14 in/h)	0 to 50 cm [0 to 20 in]	D
>100 cm [>40 in]	<60 cm [<24 in]	>10.0 μm/s (>1.42 in/h)	0 to 100 cm [0 to 40 in]	A/D
		>4.0 to ≤10.0 μm/s (>0.57 to ≤1.42 in/h)	0 to 100 cm [0 to 40 in]	B/D
		>0.40 to ≤4.0 μm/s (>0.06 to ≤0.57 in/h)	0 to 100 cm [0 to 40 in]	C/D
		≤0.40 μm/s (≤0.06 in/h)	0 to 100 cm [0 to 40 in]	D
	60 to 100 cm [24 to 40 in]	>40.0 μm/s (>5.67 in/h)	0 to 50 cm [0 to 20 in]	A
		>10.0 to ≤40.0 μm/s (>1.42 to ≤5.67 in/h)	0 to 50 cm [0 to 20 in]	B
		>1.0 to ≤10.0 μm/s (>0.14 to ≤1.42 in/h)	0 to 50 cm [0 to 20 in]	C
		≤1.0 μm/s (≤0.14 in/h)	0 to 50 cm [0 to 20 in]	D
	>100 cm [>40 in]	>10.0 μm/s (>1.42 in/h)	0 to 100 cm [0 to 40 in]	A
		>4.0 to ≤ 10.0 μm/s (>0.57 to ≤1.42 in/h)	0 to 100 cm [0 to 40 in]	B
		>0.40 to ≤4.0 μm/s (>0.06 to ≤0.57 in/h)	0 to 100 cm [0 to 40 in]	C
		≤0.40 μm/s (≤0.06 in/h)	0 to 100 cm [0 to 40 in]	D

NRCS. 2009. Hydrologic Soil Groups. Ch. 7, NEH 630 – Hydrology.

NRCS Urban Hydrology Guidance

- Technical Release 55 (TR-55) *Urban Hydrology for Small Watersheds*
  - Last updated June 1986
  - Supplemental information available at NRCS website



NRCS Urban Hydrology Guidance

Exhibit A: Hydrologic Soil Groups for the United States

AABAB	D	ACTI	D	AGUILITA	B	ALBUS	B
AABERG	D	ACTON	B	AGUIRRE	D	ALCALDE	D
AARON	C	ACUFF	B	AGUSTIN	B	ALCAN	D
AARUP	D	ACUNA	C	AHART	B	ALCESTER	B
AASTAD	B	ACY	C	AHCHEW	D	ALCOA	B
AAZDAHL	B	ADA	C	AHL	C	ALCONA	B
ABAC	D	ADABOI	C	AHLSTROM	D	ALCOT	A
ABAJO	C	ADAIR	C	AHMEEK	C	ALCOVA	B
ABALAN	D	ADAMANT	B	AHOLT	D	ALCOVY	C
ABALOBADIAH	B	ADAMS	A	AHPAH	C	ALDA, Saline	B/D
ABARCA	B	ADAMSLAKE	B	AHREN	B	ALDA	C
ABBAYE	B	ADAMSON	B	AHRNKLIN	C	ALDAPE	D
ABBEYLAKE	A	ADAMSVILLE	C	AHRS	B	ALDAX	D
ABBIE	B	ADATON	D	AHSAHKA	C	ALDEN	D
ABBOTT	D	ADAVEN	C	AHTANUM	C/D	ALDENLAKE	B
ABBOTTSPRING	B	ADCO	D	AHWAHNEE	B	ALDER	C
ABB[illegible]							C

HSGs in TR-55 (and likely in other state/local guidance) are out of date. Pre-development HSGs for soils should be determined from NRCS's Web Soil Survey.

NRCS. 1986. Urban Hydrology for Small Watersheds. Technical Release 55 (TR-55).

NRCS Urban Hydrology Guidance

Table 9–5 Runoff curve numbers for urban areas [1/]

Cover description cover type and hydrologic condition	Average percent impervious area [2/]	- - CN for hydrologic soil group - - A	 B	 C	 D
Fully developed urban areas (vegetation established)					
Open space (lawns, parks, golf courses, cemeteries, etc.) [3/]					
Poor condition (grass cover < 50%)		68	79	86	89
Fair condition (grass cover 50% to 75%)		49	69	79	84
Good condition (grass cover > 75%)		39	61	74	80
Impervious areas:					
Paved parking lots, roofs, driveways, etc. (excluding right-of-way)		98	98	98	98

NRCS. 2004. Hydrologic Soil-Cover Complexes. Ch. 9, NEH 630 – Hydrology.

NRCS Urban Hydrology Guidance

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Fu					
Op					
I		68	79	86	89
I		49	69	79	84
(		39	61	74	80
Im					
I		98	98	98	98

The urban and residential CNs given in table 9–5 were developed for typical land use relationships based on specific assumed percentages of impervious area. These CN values were developed on the assumptions that

- pervious urban areas are equivalent to pasture in good hydrologic condition,
- impervious areas have a CN of 98 and are directly connected to the drainage system, and
- the cover types listed have assumed percentages of impervious area as shown in table 9–5.

NRCS. 2004. Hydrologic Soil-Cover Complexes. Ch. 9, NEH 630 – Hydrology.



$CN_C = 74$

$CN_D = 80$

CN = ??

CN = ??

Probably>90

Abstraction Depth for "Open Space in Good Condition"

	HSG-A "sandy"	HSG-B "loamy"	HSG-C silty & clay loams	HSG-D clays & other soils w/issues
CN	39	61	74	80
Ia	3.1"	1.3"	0.7"	0.5"

NRCS Urban Hydrology Guidance

Table 9–5 Runoff curve numbers for urban areas [1/]

Cover description cover type and hydrologic condition	Average percent impervious area [2/]	-- CN for hydrologic soil group -- A	B	C	D
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(					80
Im					
I					98

The urban and residential CNs
were developed for typical lar
based o[n] specific assumed pe
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assumptions that
- pervious urban areas are
  in good hydrologic condi[t]
- impervious areas have a
  directly connected to the
- the cover types listed ha
  ages of impervious area

630.0702 Disturbed soils

As a result of construction and other disturbances, the soil profile can be altered from its natural state and the listed group assignments generally no longer apply, nor can any supposition based on the natural soil be made that will accurately describe the hydrologic properties of the disturbed soil. In these circumstances, an onsite investigation should be made to determine the hydrologic soil group. A general set of guidelines for estimating saturated hydraulic conductivity from field observable characteristics is presented in the Soil Survey Manual (Soil Survey Staff 1993).

NRCS. 2004. Hydrologic Soil-Cover Complexes. Ch. 9, NEH 630 – Hydrology.

How to Determine HSG for Disturbed Soils?

Disturbed soil profiles

As a result of urbanization, the soil profile may be considerably altered and the listed group classification may no longer apply. In these circumstances, use the following to determine HSG according to the texture of the new surface soil, provided that significant compaction has not occurred (Brakensiek and Rawls 1983).

HSG	*Soil textures*
A	Sand, loamy sand, or sandy loam
B	Silt loam or loam
C	Sandy clay loam
D	Clay loam, silty clay loam, sandy clay, silty clay, or clay

NRCS. 1986. Urban Hydrology for Small Watersheds. Technical Release 55 (TR-55).

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NRCS. 1986. Urban Hydrology for Small Watersheds. Technical Release 55 (TR-55).

Soil Compaction

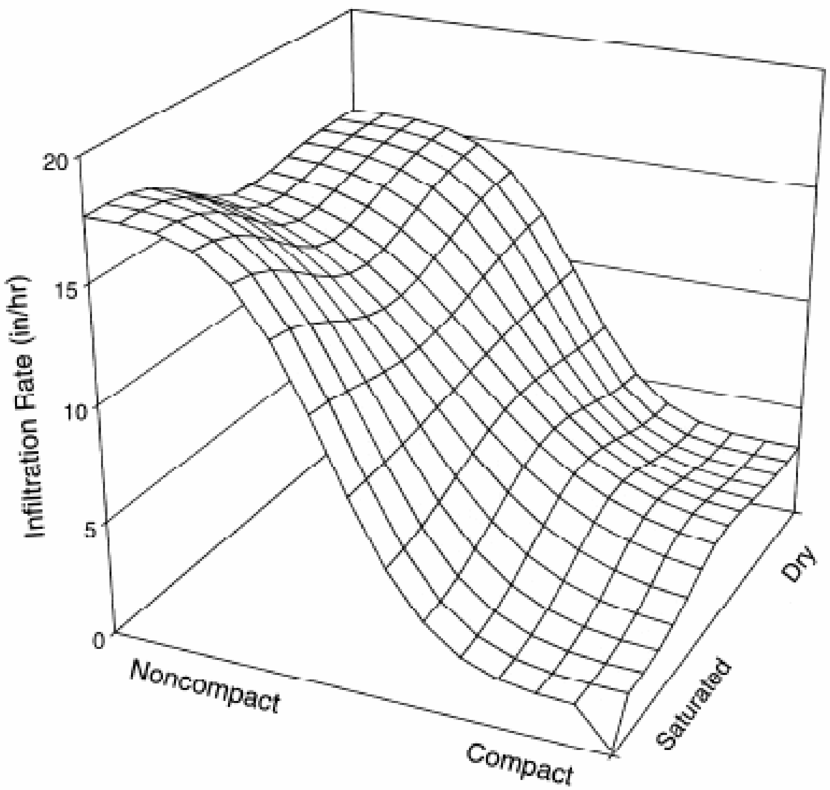


Figure 8a. Interactions of soil moisture and compaction on infiltration rates for sandy urban soils (Pitt, *et al.* 1999).

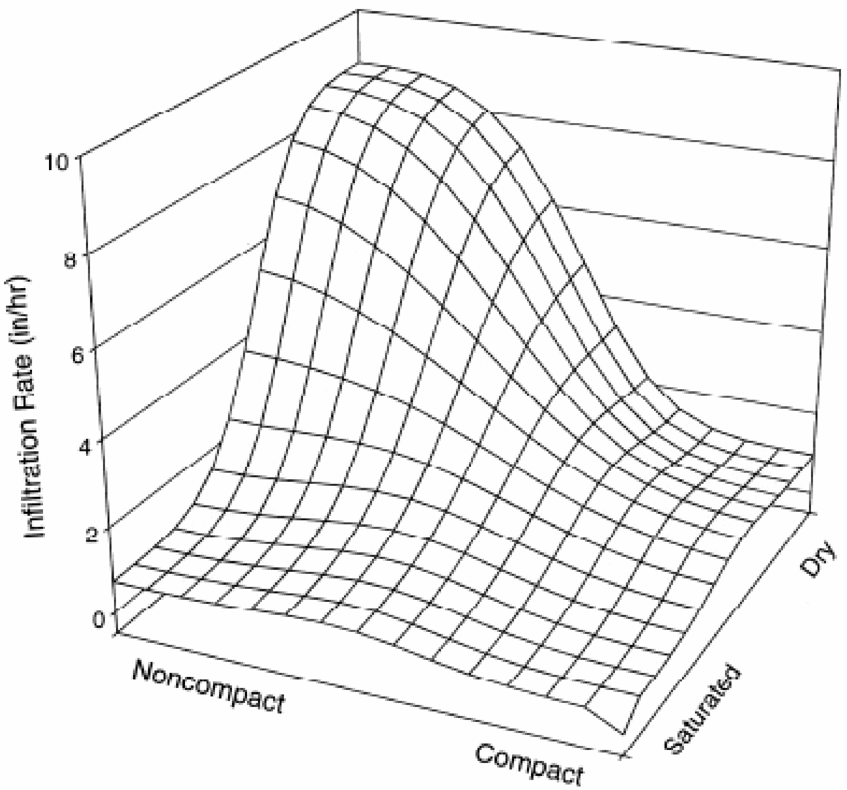
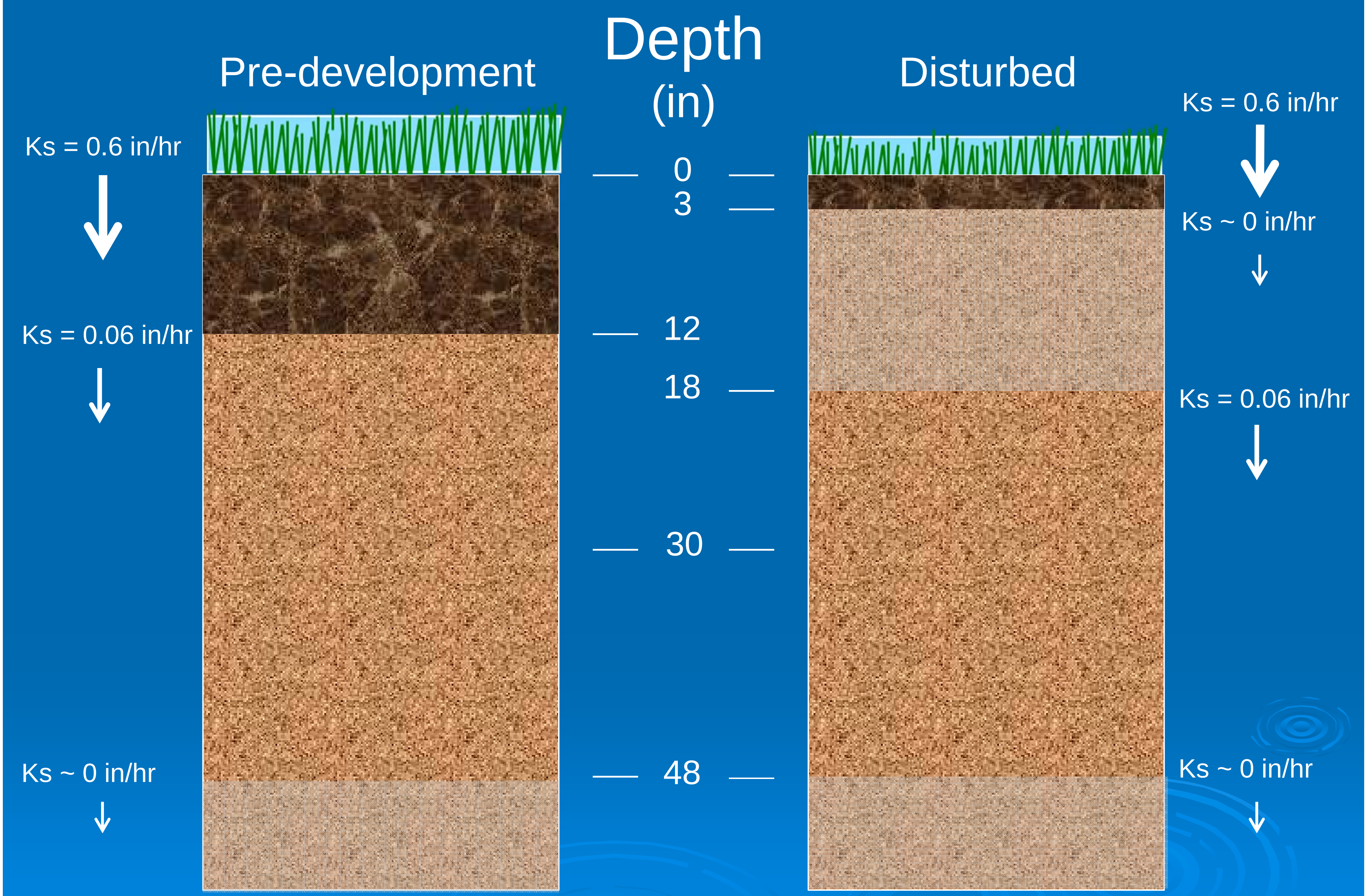


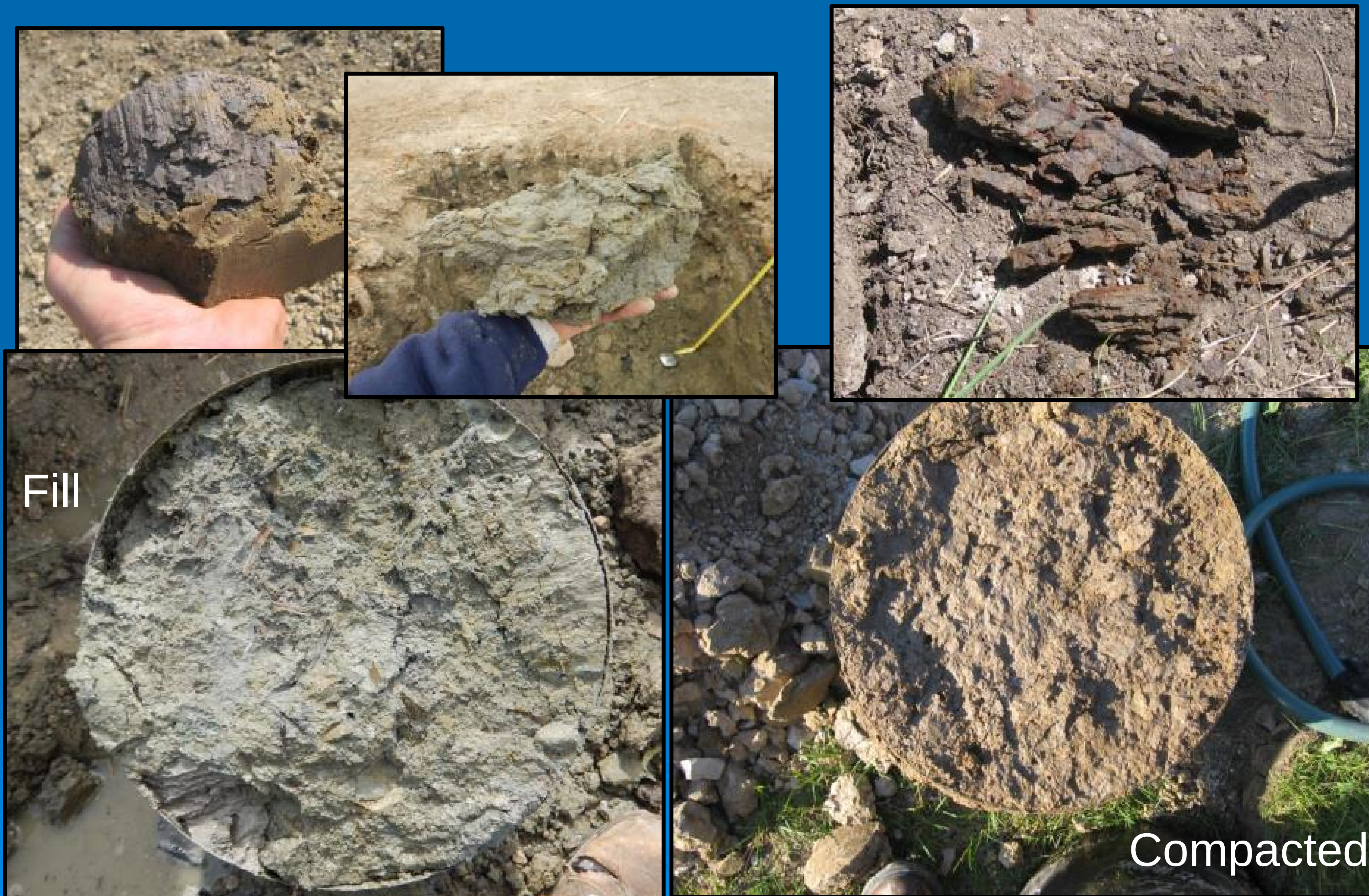
Figure 8b. Interactions of soil moisture and compaction on infiltration rates for clayey urban soils (Pitt, *et al.* 1999).



Soil Profile Comparison

Undeveloped Soil Profile

Disturbed Soil Profile



Post-disturbance Hydrologic Soil Group (HSG)

Table 7–2 Criteria for assignment of hydrologic soil groups when any water impermeable layer exists at a depth greater than 100 centimeters [40 inches]

Soil property	Hydrologic soil group A	Hydrologic soil group B	Hydrologic soil group C	Hydrologic soil group D
Saturated hydraulic conductivity of the least transmissive layer	>10 μm/s (>1.42 in/h)	≤10.0 to >4.0 μm/s (≤1.42 to >57 in/h)	≤4.0 to >0.40 μm/s (≤0.57 to >0.06 in/h)	≤0.40 μm/s (≤0.06 in/h)
	and	and	and	and/or
Depth to water impermeable layer	>100 cm [>40 in]	>100 cm [>40 in]	>100 cm [>40 in]	>100 cm [>40 in]
	and	and	and	and/or
Depth to high water table	>100 cm [>40 in]	>100 cm [>40 in]	>100 cm [>40 in]	>100 cm [>40 in]

NRCS. 2007. Hydrologic Soil Groups. Ch. 7, NEH 630 – Hydrology.

Rainwater and Land Development

Lan

Ohio's S
Land Dev

Ohio Department
Division of Soil ar

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Columbus, Ohio 43229-6
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Appendix 9: Adjusting Hydrologic Soil Group for Construction

This appendix provides hydrologic soil group (HSG) values for undisturbed Ohio soils and predictable HSG values for Ohio soils that are altered by construction practices.

The following tables contain the HSGs and predicted HSGs for post-construction that were developed by applying the HSG criteria to modeled representative post-construction soil profiles. The modeled scenario consisted of the removal of the topsoil and subsoil to a depth of 18 inches and the compaction of the zone from 0 to 6 inches at the new surface. A fuller explanation of this process is available at the end of this appendix.

Soil Map Unit Component	HSG[1]	Post-Const HSG
Aaron	C	D
Abscota Variant (Warren)	A	No Eval.
Adrian	A/D	D
Aetna	B/D	D
Alexandria	C	D
Alford	B	D
Algansee	A/D	D
Algiers	B/D	D
Allegheny	B	C
Allegheny Variant (Belmont, Pike)	B	No Eval.
Allis	D	D
Alvada	B/D	D
Amanda	C	D
Amanda Variant (Licking)	B	No Eval.
Arkport	A	A
Ashton	B	D

Soil Map Unit Component	HSG[1]	Post-Const HSG
Barkcamp (CL surface)	A	A
Barkcamp (L surface)	A	B
Beasley	C	No Eval.
Beaucoup	C/D	D
Belmore	B	C
Belpre	C	No Eval.
Bennington	C/D	D
Berks	B	D
Bethesda	C	D
Biglick	D	D
Birkbeck	B	D
Bixler	B	D
Blairton	C	No Eval.
Blakeslee	B/D	D
Blanchester	C/D	D
Blount	C/D	D

Neil Martin

USDA-NRCS soil scientist
- retired from ODNR, Division of Soil and Water Conservation

HSG Adjustment Procedure

- Removal of the top 18 inches of soil.
- Compaction of the top 6 inches of the resulting soil.
- Use texture and adjusted bulk density in the Soil Water Characteristics calculator to estimate Ksat.

Soil Water Characteristic Estimates by Texture and Organic Matter for Hydrologic Solutions

K. E. Saxton and W. J. Rawls

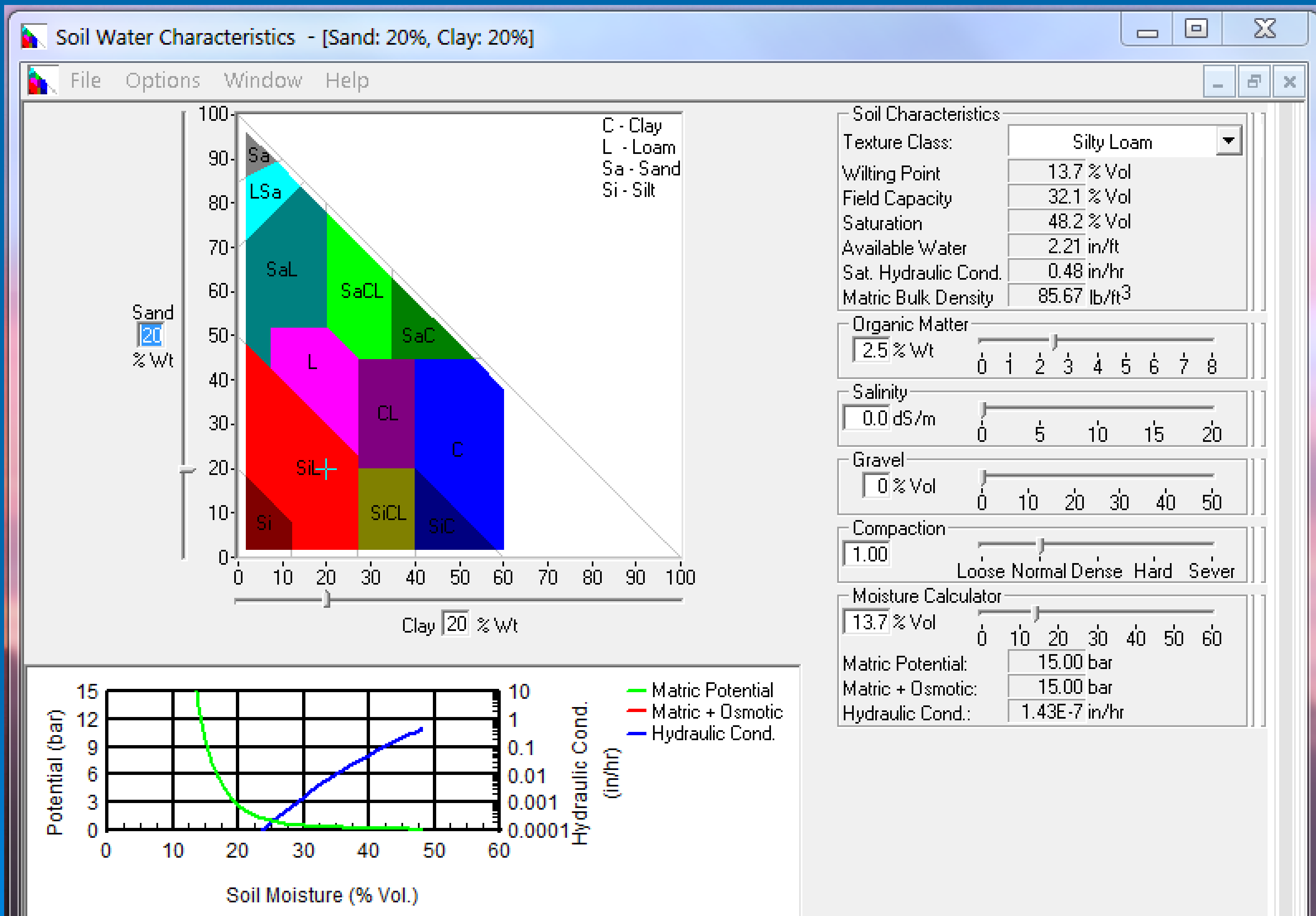
ABSTRACT

Hydrologic analyses often involve the evaluation of soil water infiltration, conductivity, storage, and plant-water relationships. To define the hydrologic soil water effects requires estimating soil water characteristics for water potential and hydraulic conductivity using soil variables such as texture, organic matter (OM), and structure. Field or laboratory measurements are difficult, costly, and often impractical for many hydrologic analyses. Statistical correlations between soil texture, soil water potential, and hydraulic conductivity can provide estimates sufficiently accurate for many analyses and decisions. This study developed new soil water characteristic equations from the currently available USDA soil database using only the readily available variables of soil texture and OM. These equations are similar to those previously reported by Saxton et al. but include more variables and application range. They were combined with previously reported relationships for tensions and conductivities and the effects of density, gravel, and salinity to form a comprehensive predictive system of soil water characteristics for agricultural water management and hydrologic analyses. Verification was performed using independent data sets for a wide range of soil textures. The predictive system was programmed for a graphical computerized model to provide easy application and rapid solutions and is available at http://hydrolab.arsusda.gov/soilwater/Index.htm.

characteristics (Van Genuchten and Leij, 1992). Application of this knowledge is imperative for hydrologic simulation within natural landscapes. However, hydrologists often do not have the capability or time to perform field or laboratory determinations. Estimated values can be determined from local soil maps and published water retention and saturated conductivity estimates, but these methods often do not provide sufficient range or accuracy for computerized hydrologic analyses.

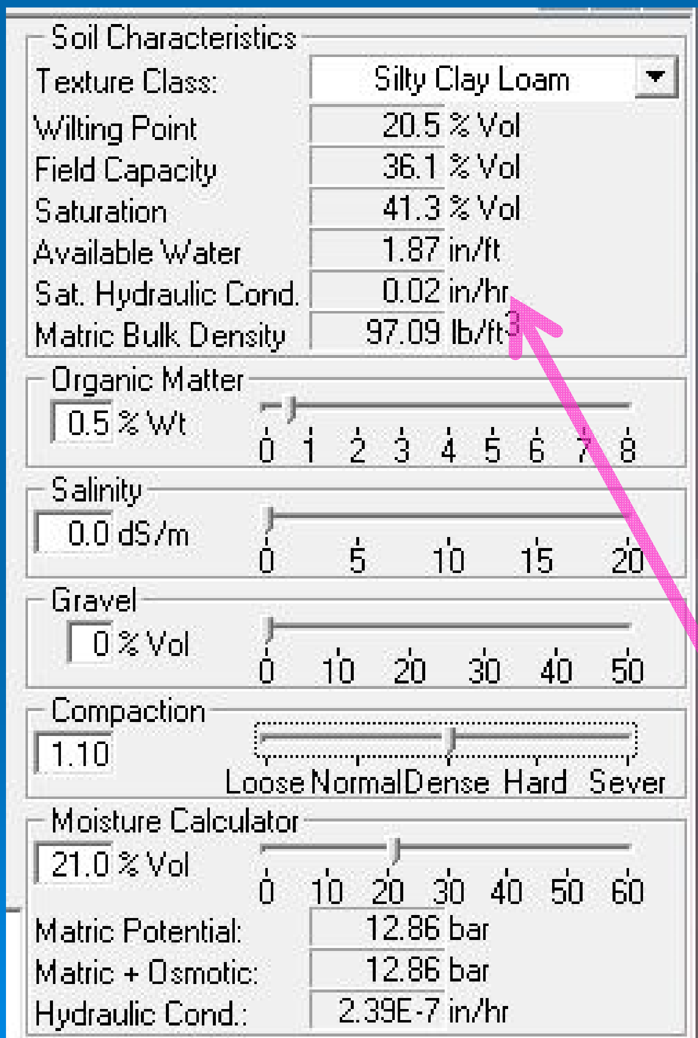
The texture based method reported by Saxton et al. (1986), largely based on the data set and analyses of Rawls et al. (1982), has been successfully applied to a wide variety of analyses, particularly those of agricultural hydrology and water management, for example, SPAW model (Saxton and Willey, 1999, 2004, 2006). Other methods have provided similar results but with limited versatility (Williams et al., 1992; Rawls et al., 1992; Stolte et al., 1994). Recent results of pedotransfer functions (Pachepsky and Rawls, 2005) are an example of modern equations that cannot be readily applied because the input requirements are beyond that cus-

Soil Water Characteristics Calculator



http://hydrolab.arsusda.gov/soilwater/Index.htm

Using Soil Water Characteristics Calculator to Estimate Adjusted Ksat



1. Select soil texture class based on soil survey
2. Reduce organic matter to 0.5%
3. Increase “Compaction” to 1.10
4. Read Sat. Hydr. Cond.

HSG Adjustment Procedure

- Removal of the top 18 inches of soil.
- Compaction of the top 6 inches of the resulting soil.
- Use texture and adjusted bulk density in the Soil Water Characteristics calculator to estimate Ksat.
- Use NRCS guidance to assign HSG.

Table 7–1 Criteria for assignment of hydrologic soil group (HSG)

Depth to water impermeable layer [1/]	Depth to high water table [2/]	K_{sat} of least transmissive layer in depth range	K_{sat} depth range	HSG [3/]
<50 cm [<20 in]	—	—	—	D
50 to 100 cm [20 to 40 in]	<60 cm [<24 in]	>40.0 μm/s (>5.67 in/h)	0 to 60 cm [0 to 24 in]	A/D
		>10.0 to ≤40.0 μm/s (>1.42 to ≤5.67 in/h)	0 to 60 cm [0 to 24 in]	B/D
		>1.0 to ≤10.0 μm/s (>0.14 to ≤1.42 in/h)	0 to 60 cm [0 to 24 in]	C/D
		≤1.0 μm/s (≤0.14 in/h)	0 to 60 cm [0 to 24 in]	D
	≥60 cm [≥24 in]	>40.0 μm/s (>5.67 in/h)	0 to 50 cm [0 to 20 in]	A
		>10.0 to ≤40.0 μm/s (>1.42 to ≤5.67 in/h)	0 to 50 cm [0 to 20 in]	B
		>1.0 to ≤10.0 μm/s (>0.14 to ≤1.42 in/h)	0 to 50 cm [0 to 20 in]	C
		≤1.0 μm/s (≤0.14 in/h)	0 to 50 cm [0 to 20 in]	D
>100 cm [>40 in]	<60 cm [<24 in]	>10.0 μm/s (>1.42 in/h)	0 to 100 cm [0 to 40 in]	A/D
		>4.0 to ≤10.0 μm/s (>0.57 to ≤1.42 in/h)	0 to 100 cm [0 to 40 in]	B/D
		>0.40 to ≤4.0 μm/s (>0.06 to ≤0.57 in/h)	0 to 100 cm [0 to 40 in]	C/D
		≤0.40 μm/s (≤0.06 in/h)	0 to 100 cm [0 to 40 in]	D
	60 to 100 cm [24 to 40 in]	>40.0 μm/s (>5.67 in/h)	0 to 50 cm [0 to 20 in]	A
		>10.0 to ≤40.0 μm/s (>1.42 to ≤5.67 in/h)	0 to 50 cm [0 to 20 in]	B
		>1.0 to ≤10.0 μm/s (>0.14 to ≤1.42 in/h)	0 to 50 cm [0 to 20 in]	C
		≤1.0 μm/s (≤0.14 in/h)	0 to 50 cm [0 to 20 in]	D
	>100 cm [>40 in]	>10.0 μm/s (>1.42 in/h)	0 to 100 cm [0 to 40 in]	A
		>4.0 to ≤ 10.0 μm/s (>0.57 to ≤1.42 in/h)	0 to 100 cm [0 to 40 in]	B
		>0.40 to ≤4.0 μm/s (>0.06 to ≤0.57 in/h)	0 to 100 cm [0 to 40 in]	C
		≤0.40 μm/s (≤0.06 in/h)	0 to 100 cm [0 to 40 in]	D

Post-development HSG

Pre-Constr HSG	Post-Constr HSG	Number
A	A	16
	B	4
	C	8
	D	5
B	A	2
	B	2
	C	21
	D	35
C	C	8
	D	66
D, /D	D	300
A, B, C	Not Rated	101

Recommendations

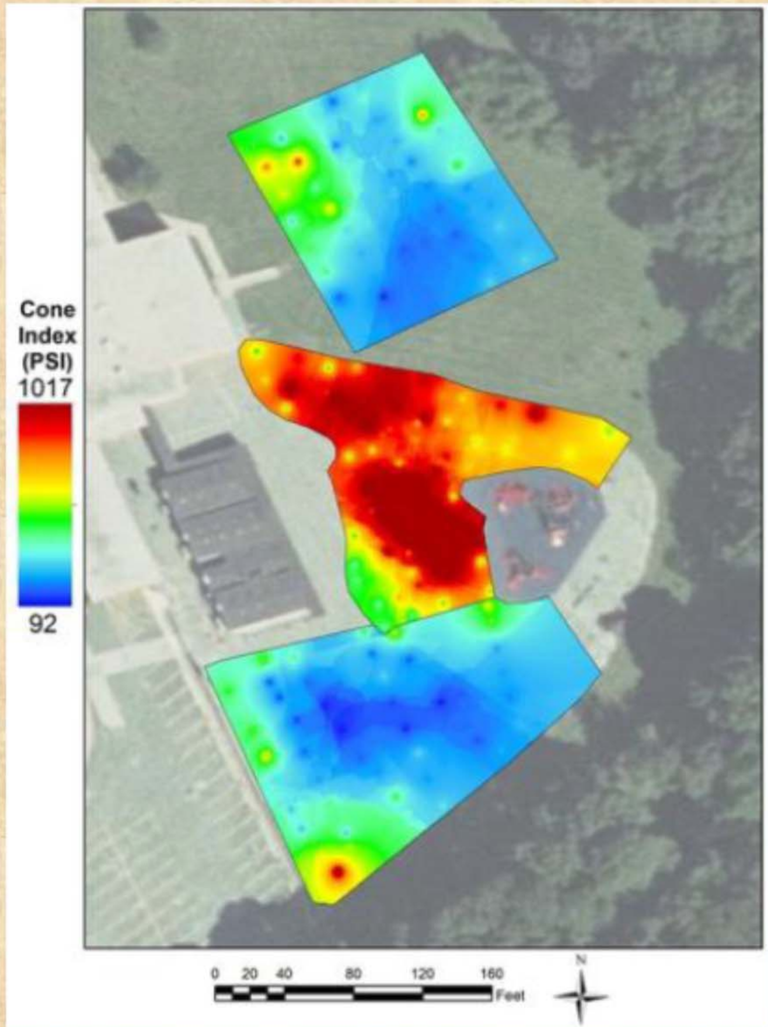
For post-development Curve Numbers:

- Undisturbed areas can be treated as “open space in good condition.”
- For all disturbed areas use post-construction HSGs published in Rainwater and Land Development Manual.

- Ohio EPA staff are developing guidelines for soil renovation criteria to improve soil function and HSG.

Decompaction - Deep Ripping and Amendment

Yorkwood Elementary School



9 months post-treatment

Stu Schwartz Graphic

Top Soil Specification

Salem, Oregon Topsoil Standard

Soil Amendment Methods

There are three different methods by which disturbed soils can be amended. Review each method to determine which is the best option for your project. The three methods are:

- Stockpile and Reuse Existing Topsoil
- Import Topsoil
- Till in Compost

Stockpile Existing Topsoil

- Prior to construction activities, scrape off existing topsoil to a minimum of eight inches.
- Stockpile the topsoil onsite and protect with appropriate erosion control measures.
- Replace topsoil over the disturbed area after construction, taking care not to compact it.

Import Topsoil

- Scarify disturbed soil to a depth of six inches.
- Place imported topsoil over the disturbed soil to a depth of eight inches.
- Do not compact the topsoil, rather water or roll to 85 percent max dry density.
- Imported topsoil should meet the requirements specified in Appendix 4G of the Salem Public Works Design Manual.

Imported Topsoil

- *Silt—25 percent*
- *Clay—25 percent*
- *Sand—25 percent*
- *Compost—25 percent*

See Appendix 4G of the Public Works Design Manual for specifications.

Rain Dog Designs Seattle

Till in Compost

- Place compost to a depth of three inches over the disturbed soil.
- Till compost into the disturbed soil to a depth of eight inches.
- If surface ponding occurs, add sand and re-till until infiltration performance is improved.
- Compost should meet the requirements specified in Appendix 4G of the Salem Public Works Design Manual.

Functional Urban Soils

$CN_C = 74$
$CN_D = 80$

Infiltration Capacity
> 0.5 in/hr

Abstraction Depth
HSG-C > 0.75”
HSG-D > 0.5”

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