Board of Water and Soil Resources

Controlling Groundwater Levels in Agricultural Landscapes with Drain Tile and Drainage Water Management

Tim Gillette,
Conservation Drainage Engineer,
Board of Water and Soil Resources

Where we are going.

I. Introduction to Drainage

II. Agricultural Drainage Basics

III. Introduction To Subsurface Drainage Design

IV. Introduction To Drainage Water Management (DWM) Design

Introduction to Drainage – Ancient History

Urban Drainage in
Ancient Pakistan
Circa 2600 BCE

Introduction to Drainage – Modern History – Open Ditch

Serious Dredges Made Large Ditches – Cooks, Operators, Everybody on Board.

Introduction to Drainage – Modern History – Tile

John Johnston
“Father of Tile Drainage”
in the United States

Brought Tile Molds to America
in 1838

Drain Tile Museum
Geneva, New York
Clay – Concrete - Plastic

Introduction to Drainage – Modern History – Tile Hand Dug

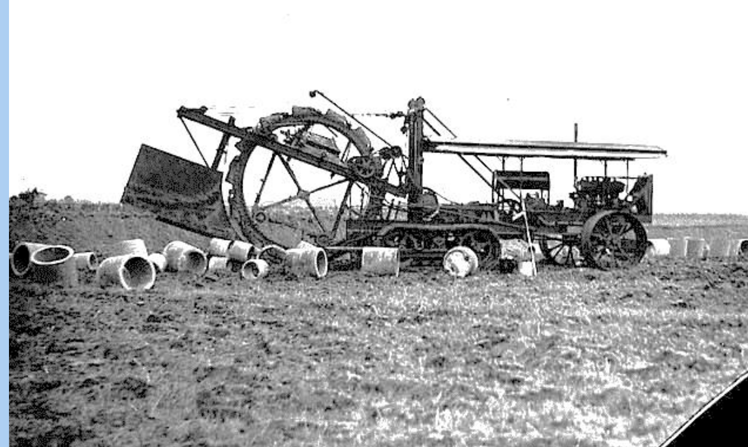
First – Tile Was Hand Dug

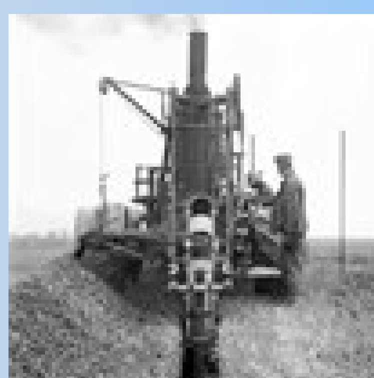
(Just think of hand-digging 72 miles of tile on 320 acres like on the John Johnston Farm)

Minnesota Board of Water & Soil Resources

Introduction to Drainage – Modern History – Machine Dug

Then – Machine Trenching





Introduction to Drainage – Modern Tiling – GPS Guided

And Then Plowing In
With GPS

Introduction to Drainage – Landscapes – Urban/Roads/Agriculture

Urban

Roads

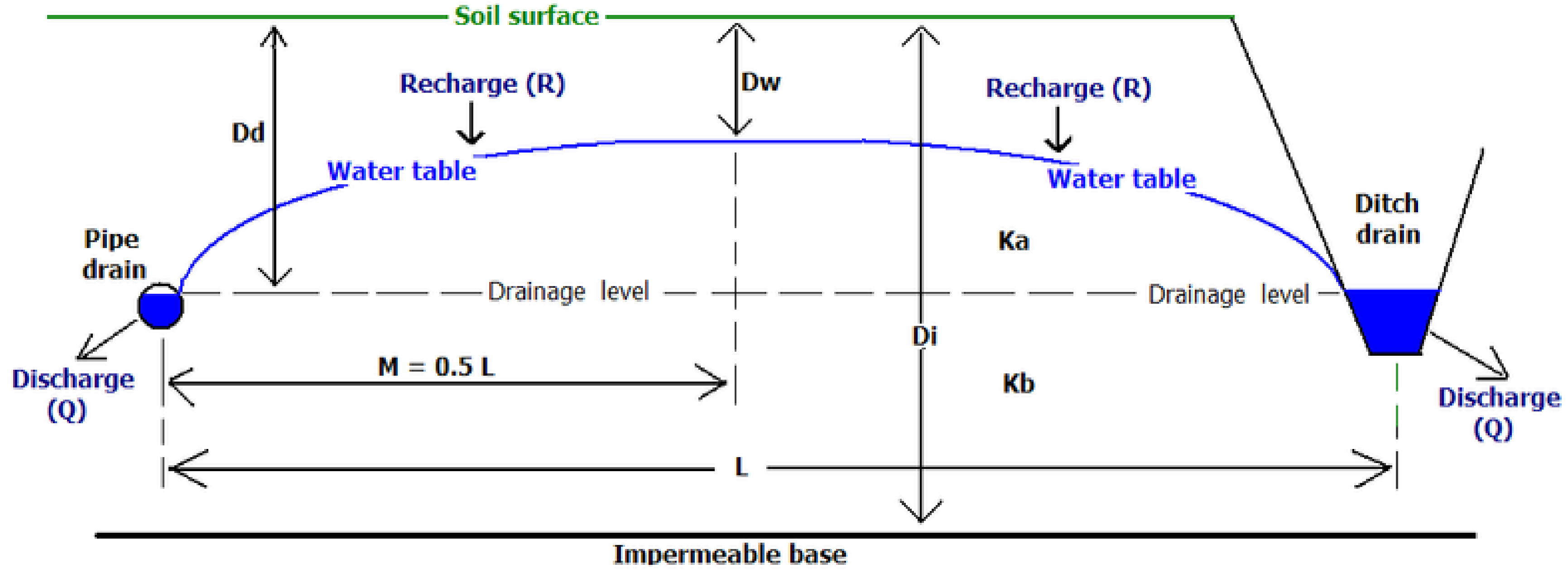
Agriculture

Introduction to Drainage – Types

Surface – Channels, Ditches, Canals, and Swales along with Various Structures

Subsurface – Storm Drains, Sanitary Sewer, *and* Agricultural Drainage Tile

Introduction to Drainage – Controlling the Water Table



Geometry subsurface drainage system by pipes or ditches

D = depth   K = hydraulic conductivity   L = Drain spacing

Graphics Courtesy of R.J. Oosterbaan

Introduction to Drainage – Why We Drain.

Four Reasons for Drainage:

1. Making Livable Cities
2. Protecting Roads and Travelers
3. Protecting and Enhancing Human Health
4. Making Agricultural Lands Available for Food Production

Drainage & Health: Malaria?

- 1830's **work stopped** on the Illinois-Michigan Canal because of **costs of malaria**.
- Illinois had **settlements abandoned** because of malaria in 1830's
- Fort Snelling: **66 cases per 1000 people** per year between 1829-1838
- **Dr. Mayo moved here** from Indiana to **escape malaria** in 1854.

Slide courtesy of Dr. Bruce Wilson

Malaria in the Upper Mississippi Valley:1760-1900. Ackernecht, 1945.

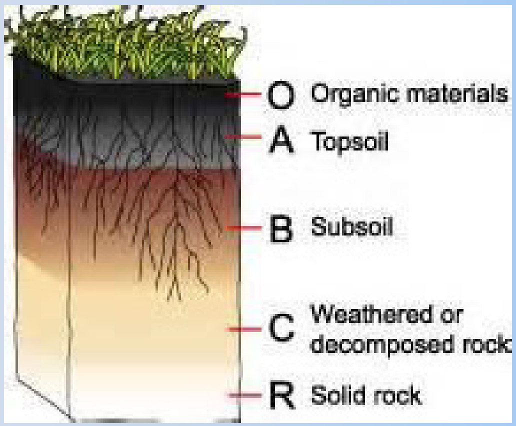
Agricultural Drainage Basics – Elements Effecting Drainage

Five Key Elements Effecting Drainage:

1. Soils
2. Water – Rainfall/Watercycle
3. Topography
4. Climate
5. Land Use

Agricultural Drainage Basics – Soils

SOILS



Hydrologic Soil Groups

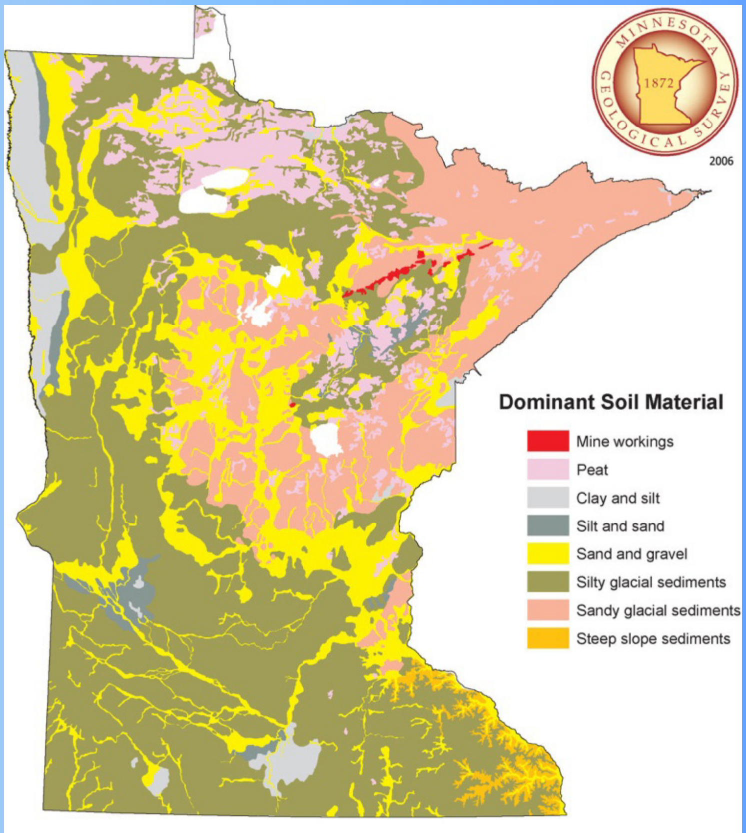
HSG Soil textures

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



Agricultural Drainage Basics – Water

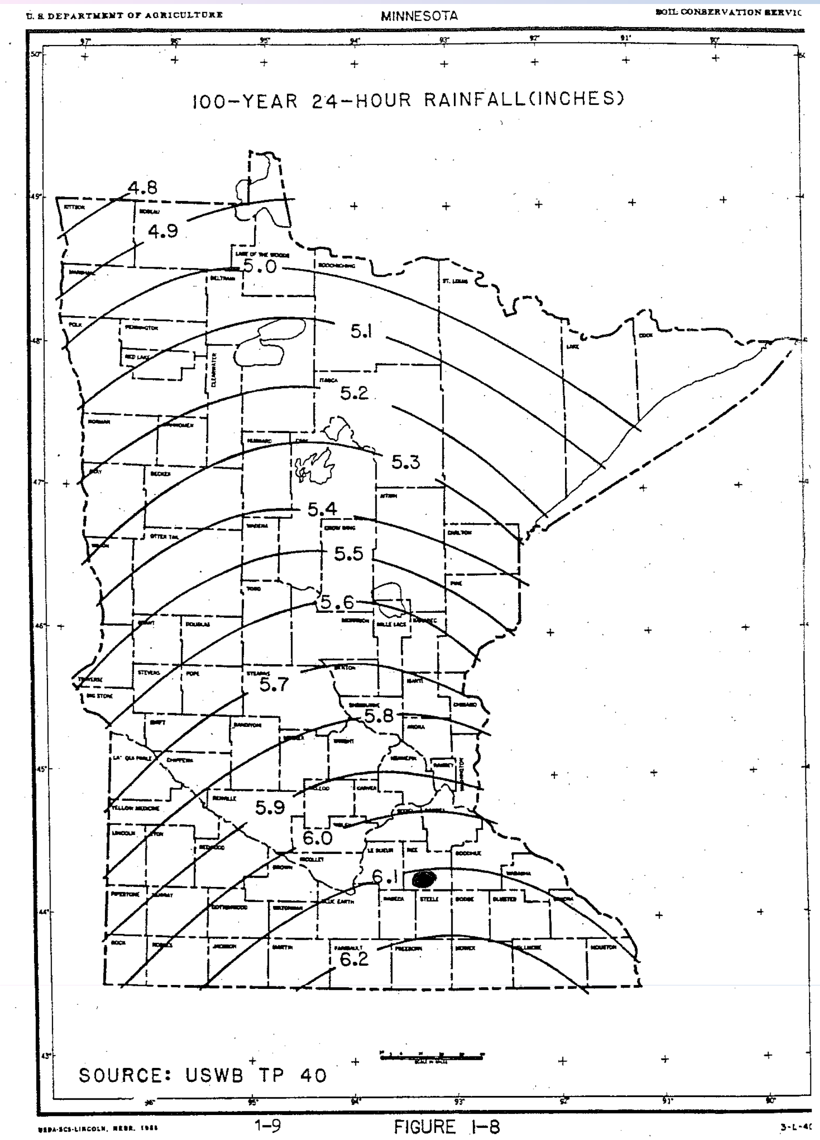


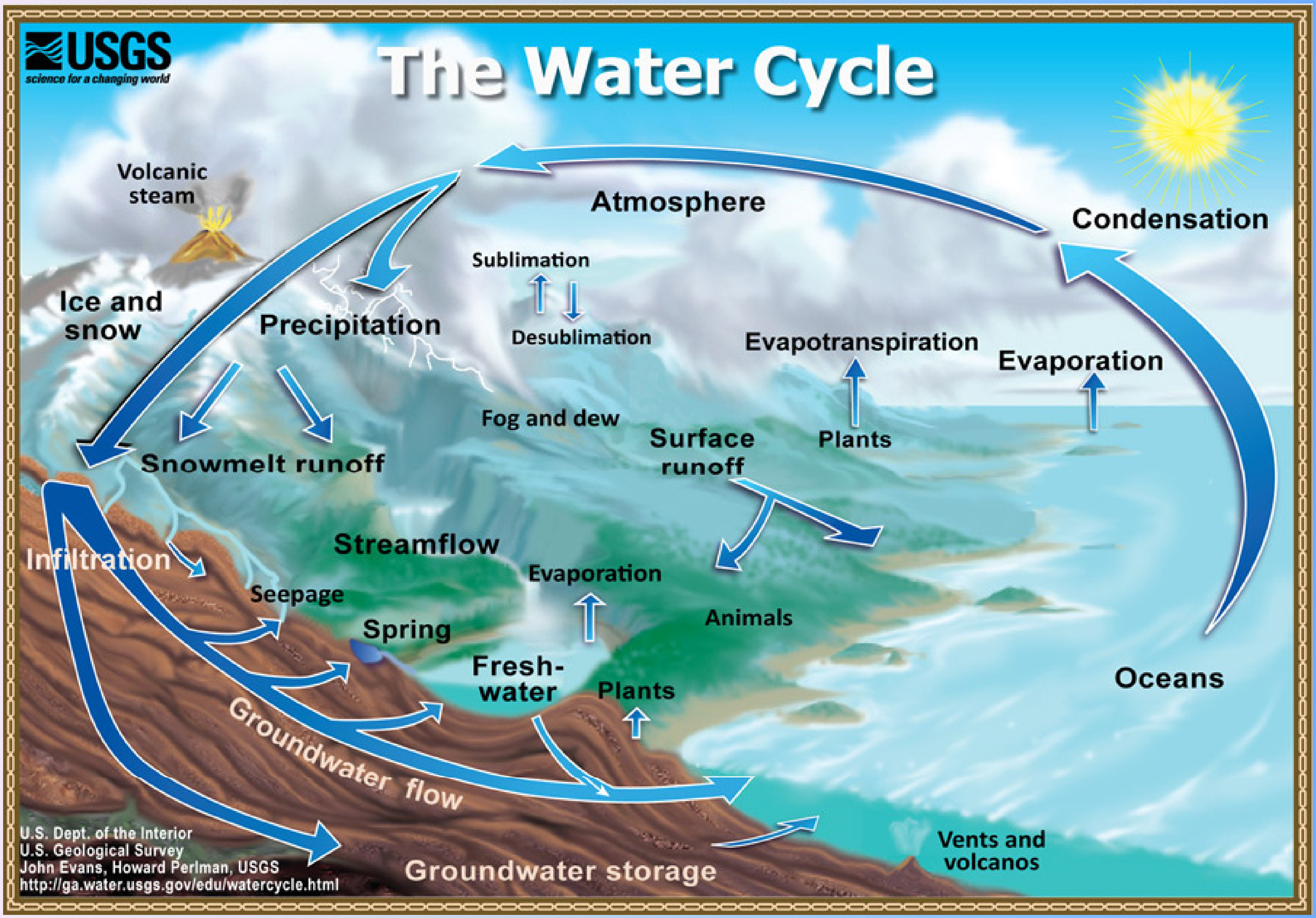
Table 1.
Precipitation for Different Storm Events

SCS Type II 24-hour storm event	Precipitation
1-Year	2.3 inches
2-Year	2.8 inches
10-Year	4.25 inches
100-Year	6.1 inches
100-year 10-day snow melt	7.05 inches

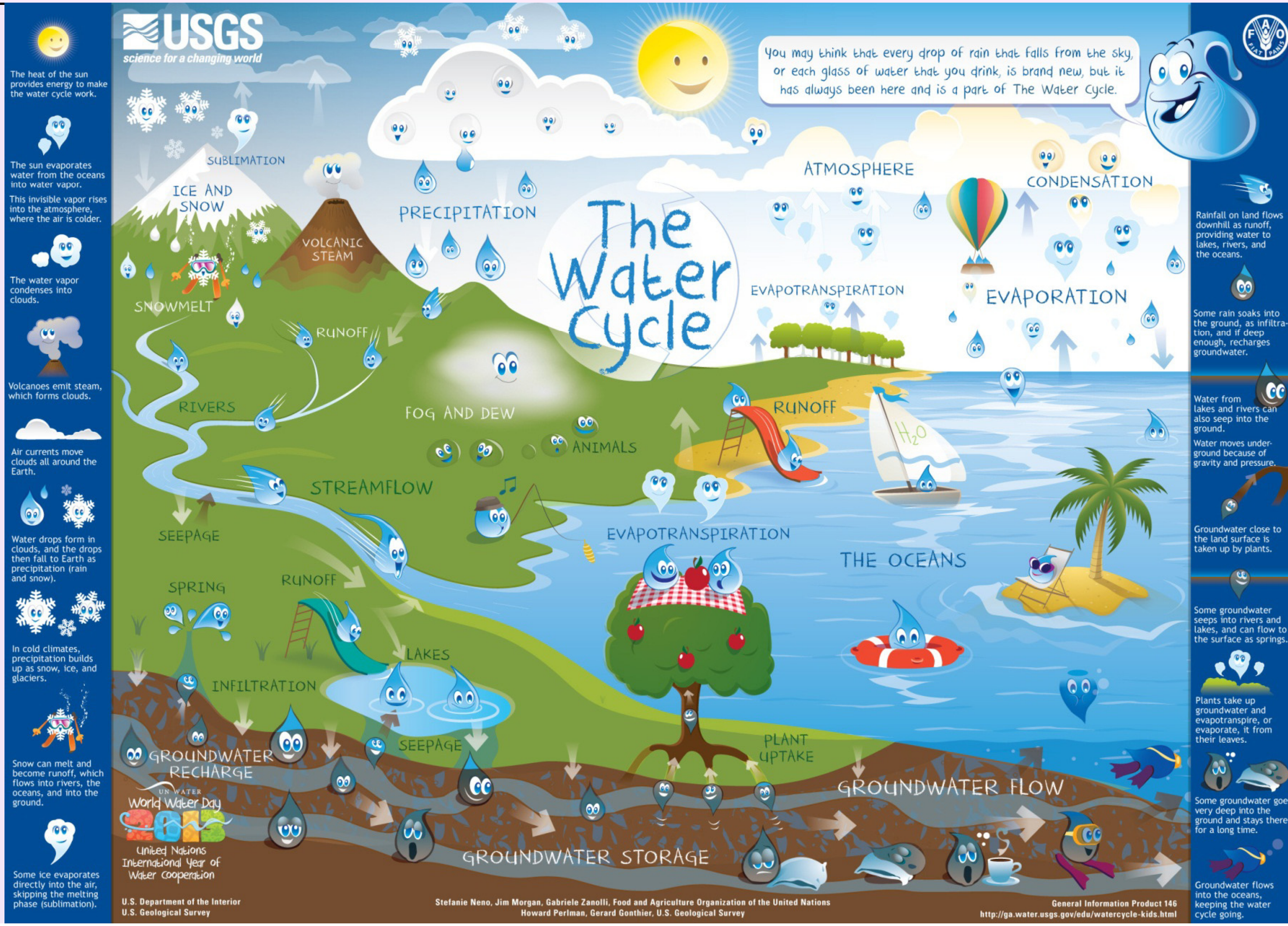
Northfield, Minnesota, Code of Ordinances >> PART II - NORTHFIELD CODE >> Chapter 22 - ENVIRONMENT >> ARTICLE VI. - SURFACE WATER MANAGEMENT >> DIVISION 2. STORMWATER MANAGEMENT

RAINFALL

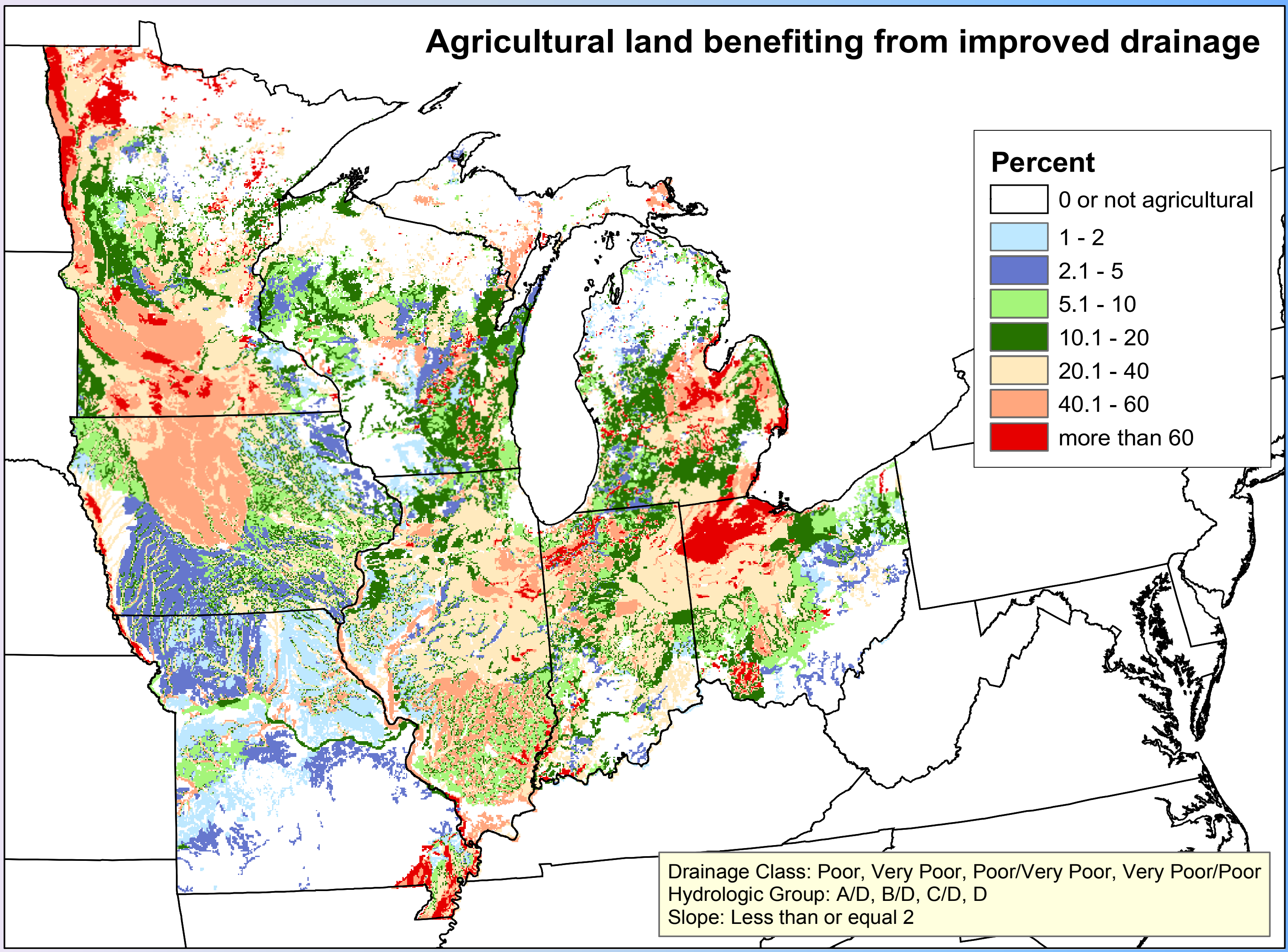
Agricultural Drainage Basics – Water - Watercycle



Agricultural Drainage Basics – Water - Watercycle

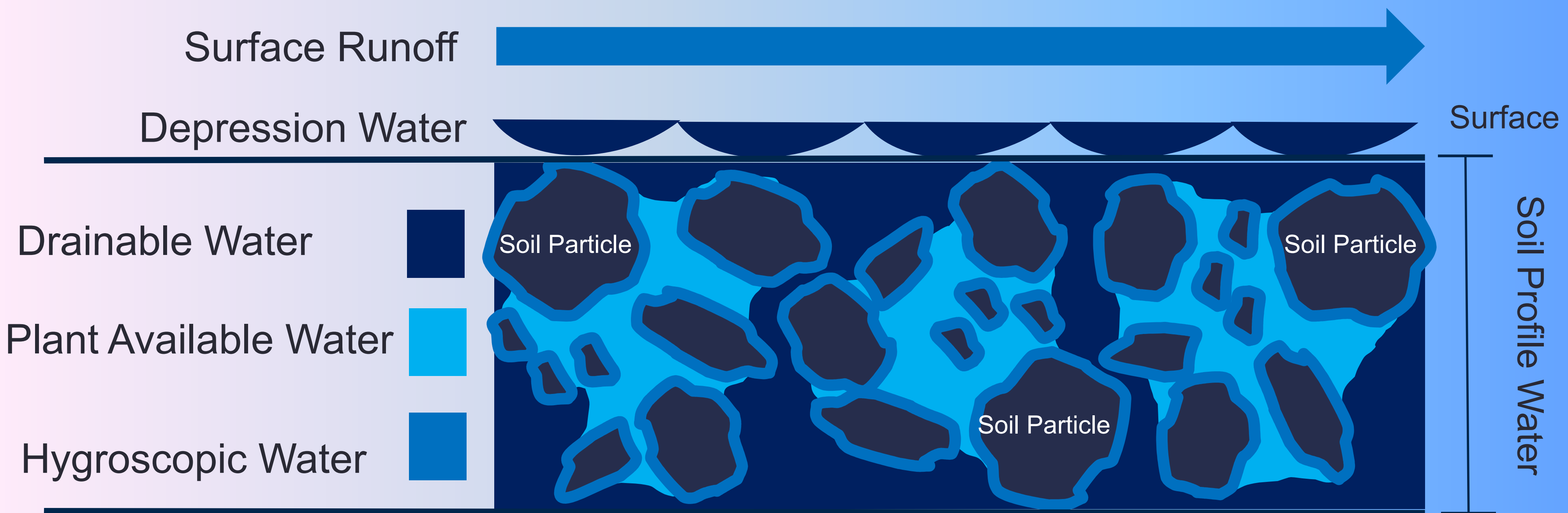


Poorly Drained Soils in the Upper Midwest



Courtesy of Dan Jaynes, ARS – Ames, IA

Partitioning of Soil Profile and Surface Water



Slide courtesy of Charles Fritz

Key Water Storage Categories

- **Retention** – Water stored for extended periods of time (**weeks or months**). For example a "wet" impoundment with a "permanent", or "normal" pool. *Long-term storage enables substantial evaporation and transpiration (volume reduction).*
- **Detention** – Water stored for a limited period of time (**hours or days**). For example a "dry" impoundment and the water that is only detained. *Short-term storage does not enable much evaporation and transpiration (volume reduction).*

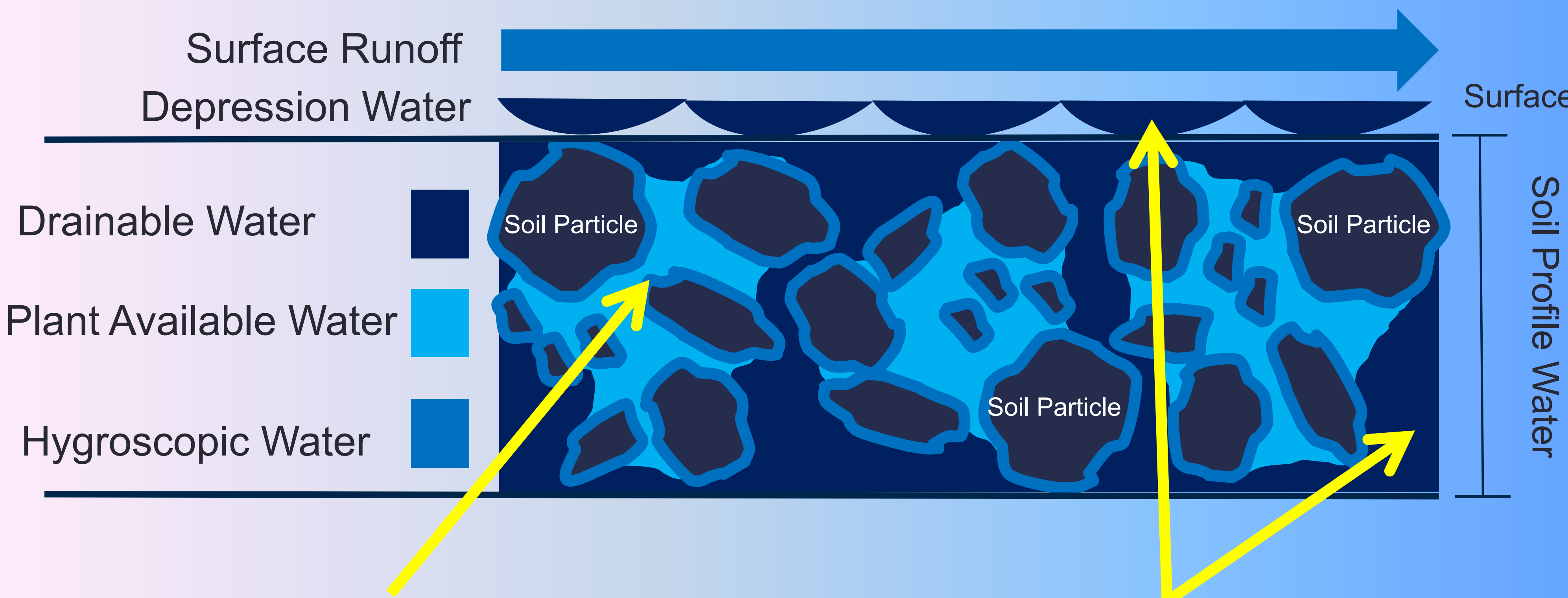

Wetland - retention


Wetland - detention


Maple River Dam - detention

Slide courtesy of Charles Fritz

Without Subsurface Drainage

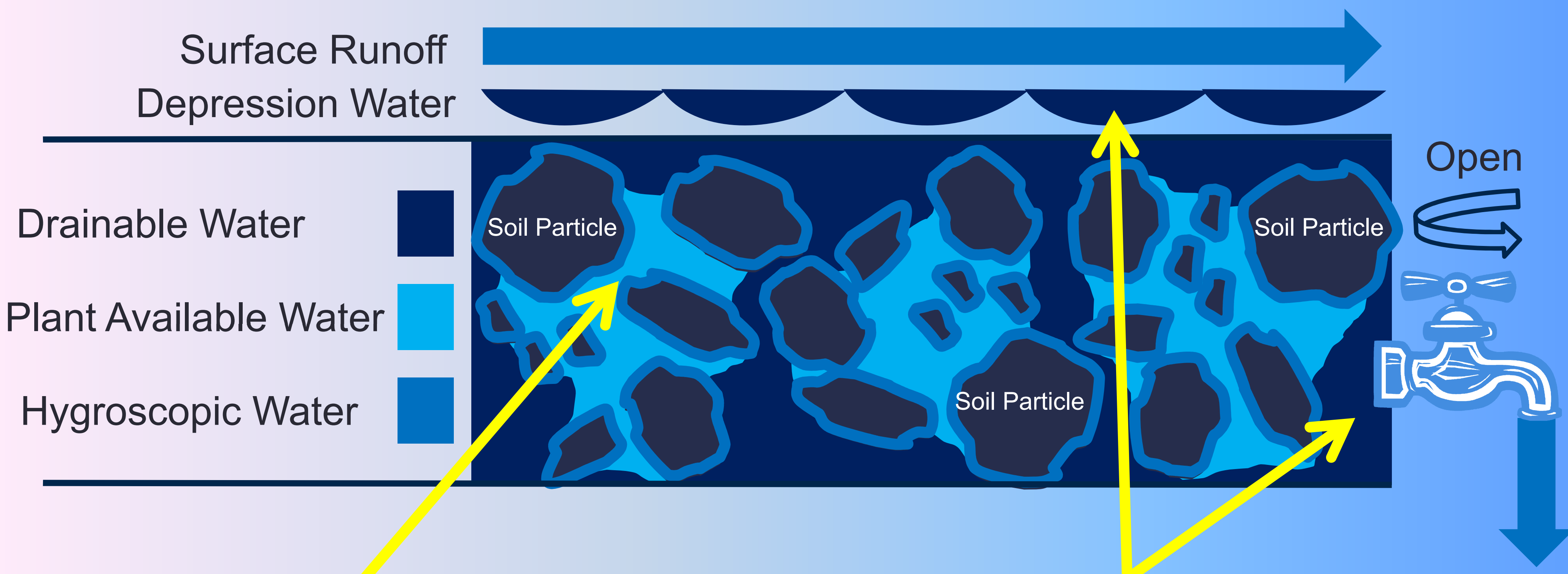


Hygroscopic and Plant Available Water =
Retention Storage

Drainable Water and Surface Depression Water =
Retention Storage

Slide courtesy of Charles Fritz

With Subsurface Drainage



Hygroscopic and Plant Available Water =

Retention Storage

~~Drainable Water and Surface Depression Water =~~

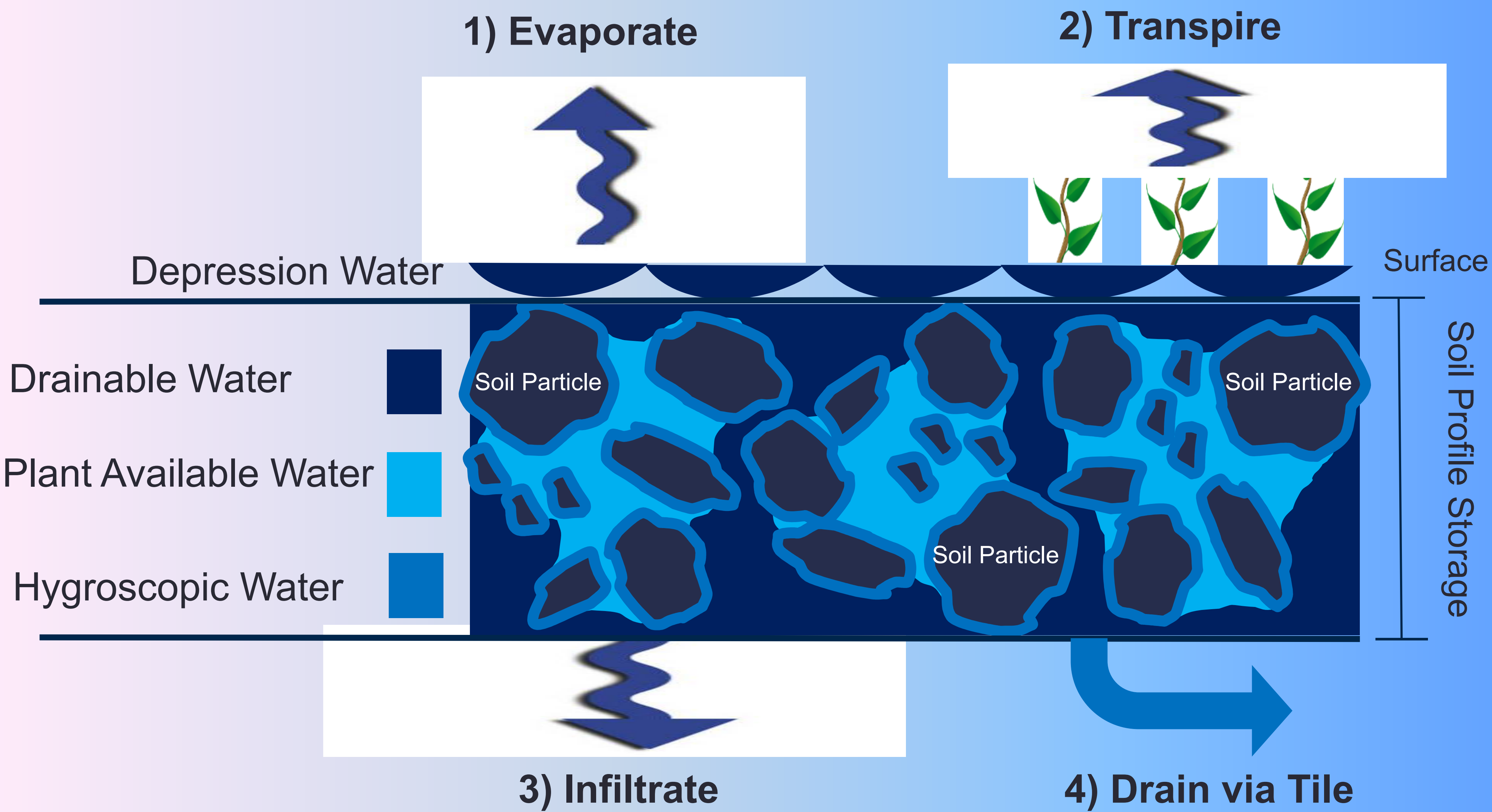
~~***Retention Storage***~~

Drainable Water and Surface Depression Water =

<u>Detention</u> Storage

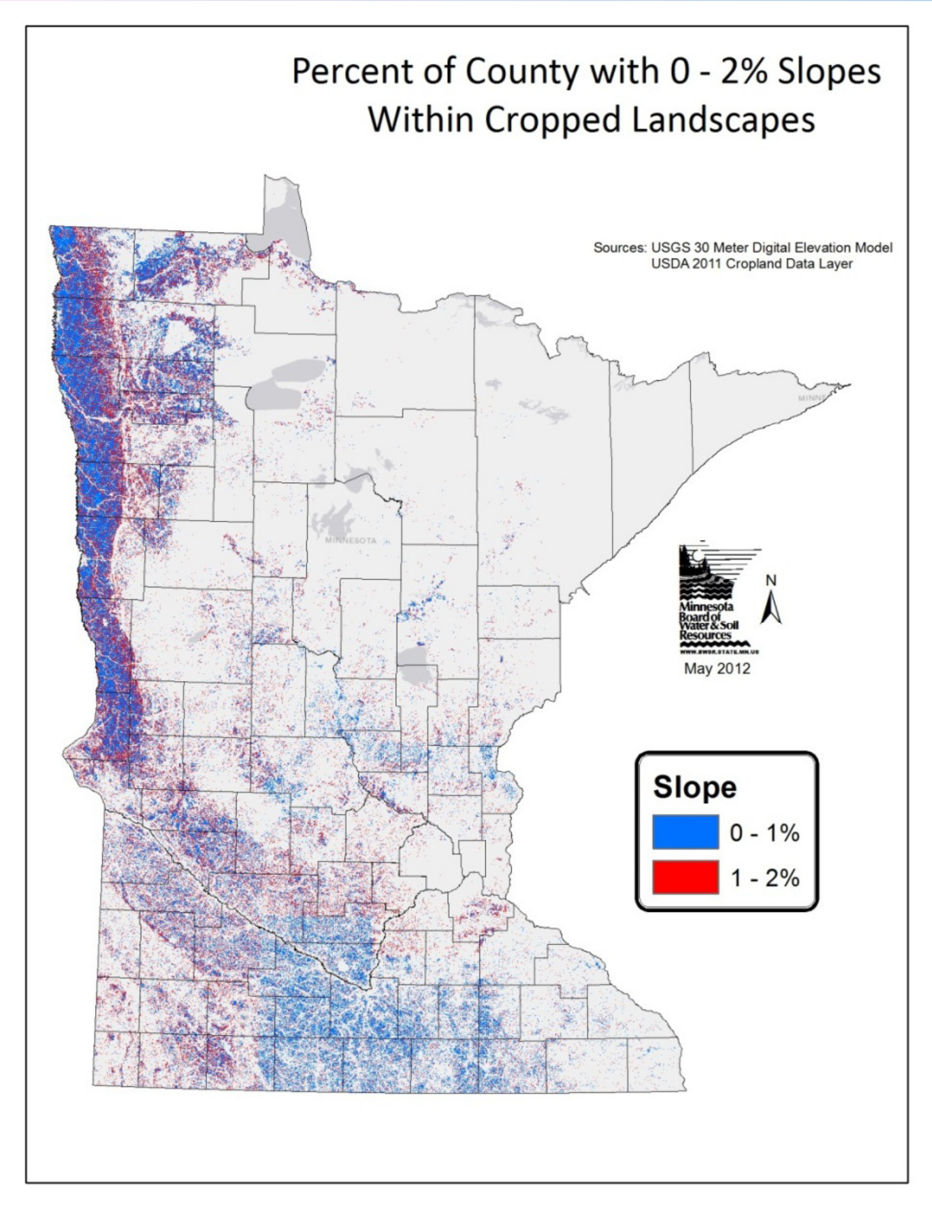
Slide courtesy of Charles Fritz

Fate of Drainable Soil Profile and Surface Depression Water



Slide courtesy of Charles Fritz

Agricultural Drainage Basics – Topography



Topography
– Friend or Foe?

Agricultural Drainage Basics – Climate

Minnesota Board of Water & Soil Resources

NOAA Atlas 14, Volume 8, Version
2NORTHFIELD 2 NNE
Station ID: 21-5987
Location name: Northfield, Minnesota, US*
Coordinates: 44.4761, -93.1486
Elevation:
Elevation (station metadata): 890ft*
* source: Google Maps

POINT PRECIPITATION FREQUENCY ESTIMATES

Sanja Perica, Deborah Martin, Sandra Pavlovic, Ishani Roy, Michael St. Laurent, Carl Trypaluk, Dale Unruh, Michael Yekta, Geoffery Bonnin

NOAA, National Weather Service, Silver Spring, Maryland

PF_tabular | PF_graphical | Maps_&_aerials

PF tabular

PDS-based point precipitation frequency estimates with 90% confidence intervals (in inches)[1]

Duration	Average recurrence interval (years)									
	1	2	5	10	25	50	100	200	500	1000
5-min	0.352 (0.284–0.442)	0.420 (0.338–0.528)	0.538 (0.432–0.678)	0.644 (0.513–0.814)	0.799 (0.618–1.05)	0.928 (0.697–1.23)	1.06 (0.769–1.43)	1.21 (0.834–1.66)	1.41 (0.933–1.98)	1.58 (1.01–2.22)
10-min	0.515 (0.415–0.647)	0.614 (0.495–0.773)	0.788 (0.632–0.993)	0.943 (0.751–1.19)	1.17 (0.905–1.54)	1.36 (1.02–1.80)	1.56 (1.13–2.10)	1.77 (1.22–2.43)	2.07 (1.37–2.90)	2.31 (1.48–3.26)
15-min	0.628 (0.506–0.789)	0.749 (0.603–0.942)	0.961 (0.771–1.21)	1.15 (0.916–1.45)	1.43 (1.10–1.87)	1.66 (1.25–2.19)	1.90 (1.37–2.56)	2.16 (1.49–2.97)	2.52 (1.67–3.54)	2.81 (1.80–3.97)
30-min	0.900 (0.726–1.13)	1.08 (0.866–1.35)	1.38 (1.11–1.74)	1.66 (1.32–2.09)	2.06 (1.59–2.71)	2.40 (1.80–3.17)	2.75 (1.99–3.71)	3.13 (2.16–4.30)	3.66 (2.42–5.14)	4.09 (2.62–5.77)
60-min	1.18 (0.949–1.48)	1.40 (1.13–1.76)	1.81 (1.45–2.28)	2.19 (1.74–2.76)	2.76 (2.15–3.66)	3.26 (2.46–4.33)	3.79 (2.75–5.13)	4.38 (3.03–6.04)	5.21 (3.45–7.34)	5.89 (3.77–8.32)
2-hr	1.46 (1.18–1.82)	1.73 (1.40–2.15)	2.23 (1.80–2.79)	2.71 (2.18–3.41)	3.47 (2.72–4.57)	4.12 (3.13–5.45)	4.83 (3.53–6.51)	5.62 (3.93–7.72)	6.76 (4.52–9.47)	7.69 (4.97–10.8)
3-hr	1.62 (1.32–2.01)	1.91 (1.55–2.38)	2.47 (2.00–3.08)	3.02 (2.43–3.78)	3.90 (3.08–5.14)	4.67 (3.57–6.18)	5.52 (4.06–7.43)	6.47 (4.55–8.88)	7.86 (5.29–11.0)	9.01 (5.85–12.6)
6-hr	1.89 (1.55–2.33)	2.21 (1.81–2.73)	2.86 (2.32–3.53)	3.49 (2.83–4.33)	4.53 (3.61–5.95)	5.45 (4.20–7.17)	6.48 (4.81–8.67)	7.63 (5.41–10.4)	9.32 (6.34–13.0)	10.7 (7.04–14.9)
12-hr	2.14 (1.76–2.61)	2.50 (2.06–3.06)	3.21 (2.63–3.93)	3.89 (3.16–4.78)	4.97 (3.97–6.44)	5.91 (4.58–7.69)	6.95 (5.18–9.24)	8.11 (5.80–11.0)	9.80 (6.71–13.5)	11.2 (7.41–15.4)
24-hr	2.46 (2.04–2.99)	2.81 (2.32–3.42)	3.50 (2.88–4.26)	4.17 (3.42–5.10)	5.27 (4.25–6.79)	6.24 (4.88–8.07)	7.32 (5.52–9.63)	8.53 (6.15–11.4)	10.3 (7.13–14.1)	11.8 (7.87–16.1)
2-day	2.86 (2.38–3.45)	3.19 (2.65–3.85)	3.85 (3.19–4.66)	4.52 (3.72–5.48)	5.62 (4.56–7.19)	6.60 (5.20–8.48)	7.70 (5.86–10.1)	8.95 (6.52–11.9)	10.8 (7.54–14.6)	12.3 (8.31–16.7)
3-day	3.12 (2.60–3.74)	3.47 (2.90–4.17)	4.17 (3.47–5.02)	4.86 (4.02–5.87)	5.98 (4.87–7.59)	6.97 (5.51–8.89)	8.08 (6.17–10.5)	9.32 (6.82–12.4)	11.1 (7.84–15.1)	12.7 (8.60–17.1)
4-day	3.33 (2.79–3.98)	3.72 (3.11–4.45)	4.46 (3.72–5.35)	5.18 (4.29–6.24)	6.32 (5.15–7.97)	7.32 (5.79–9.28)	8.42 (6.44–10.9)	9.65 (7.07–12.7)	11.4 (8.05–15.4)	12.9 (8.80–17.4)
7-day	3.87 (3.25–4.60)	4.36 (3.66–5.19)	5.24 (4.39–6.24)	6.03 (5.02–7.21)	7.22 (5.87–8.96)	8.22 (6.51–10.3)	9.28 (7.11–11.8)	10.4 (7.67–13.6)	12.0 (8.53–16.0)	13.4 (9.18–17.9)
10-day	4.38 (3.70–5.19)	4.95 (4.17–5.87)	5.92 (4.97–7.03)	6.77 (5.66–8.07)	8.01 (6.50–9.84)	9.00 (7.15–11.2)	10.0 (7.71–12.7)	11.1 (8.22–14.4)	12.7 (9.00–16.7)	13.9 (9.59–18.5)
20-day	5.98 (5.07–7.03)	6.71 (5.69–7.89)	7.90 (6.67–9.31)	8.89 (7.47–10.5)	10.3 (8.36–12.4)	11.3 (9.02–13.9)	12.4 (9.56–15.5)	13.5 (9.99–17.2)	14.9 (10.7–19.5)	16.0 (11.2–21.2)
30-day	7.38 (6.29–8.63)	8.25 (7.02–9.66)	9.64 (8.17–11.3)	10.8 (9.08–12.7)	12.3 (10.0–14.7)	13.4 (10.7–16.3)	14.5 (11.2–18.0)	15.6 (11.6–19.8)	17.0 (12.2–22.1)	18.1 (12.7–23.8)
45-day	9.20 (7.86–10.7)	10.3 (8.77–12.0)	12.0 (10.2–14.0)	13.3 (11.2–15.6)	15.0 (12.3–17.9)	16.3 (13.0–19.6)	17.4 (13.5–21.5)	18.6 (13.9–23.4)	19.9 (14.4–25.7)	20.9 (14.8–27.4)
60-day	10.8 (9.23–12.5)	12.1 (10.3–14.0)	14.0 (12.0–16.3)	15.6 (13.2–18.2)	17.5 (14.3–20.7)	18.8 (15.1–22.6)	20.1 (15.6–24.6)	21.2 (15.9–26.5)	22.5 (16.3–28.9)	23.4 (16.6–30.6)

[1] Precipitation frequency (PF) estimates in this table are based on frequency analysis of partial duration series (PDS).

Numbers in parenthesis are PF estimates at lower and upper bounds of the 90% confidence interval. The probability that precipitation frequency estimates (for a given duration and average recurrence interval) will be greater than the upper bound (or less than the lower bound) is 5%. Estimates at upper bounds are not checked against probable maximum precipitation (PMP) estimates and may be higher than currently valid PMP values.

Please refer to NOAA Atlas 14 document for more information.

Back to Top

PF graphical

The Climate "is a changin'!"

Agricultural Drainage Basics – Landuse

Minnesota Board of Water & Soil Resources

TR-55 Runoff Curve Numbers for Cultivated Agricultural Lands

Table 2-2b Runoff curve numbers for cultivated agricultural lands [1]

Cover description			Curve numbers for hydrologic soil group			
Cover type	Treatment [2]	Hydrologic condition [3]	A	B	C	D
Fallow	Bare soil	—	77	86	91	94
	Crop residue cover (CR)	Poor	76	85	90	93
		Good	74	83	88	90
Row crops	Straight row (SR)	Poor	72	81	88	91
		Good	67	78	85	89
	SR + CR	Poor	71	80	87	90
		Good	64	75	82	85
	Contoured (C)	Poor	70	79	84	88
		Good	65	75	82	86
	C + CR	Poor	69	78	83	87
		Good	64	74	81	85
	Contoured & terraced (C&T)	Poor	66	74	80	82
		Good	62	71	78	81
	C&T+ CR	Poor	65	73	79	81
		Good	61	70	77	80
Small grain	SR	Poor	65	76	84	88
		Good	63	75	83	87
	SR + CR	Poor	64	75	83	86
		Good	60	72	80	84
	C	Poor	63	74	82	85
		Good	61	73	81	84
	C + CR	Poor	62	73	81	84
		Good	60	72	80	83
	C&T	Poor	61	72	79	82
		Good	59	70	78	81
	C&T+ CR	Poor	60	71	78	81
		Good	58	69	77	80
Close-seeded or broadcast legumes or rotation meadow	SR	Poor	66	77	85	89
		Good	58	72	81	85
	C	Poor	64	75	83	85
		Good	55	69	78	83
	C&T	Poor	63	73	80	83
		Good	51	67	76	80

1 Average runoff condition, and I_a=0.2S

2 Crop residue cover applies only if residue is on at least 5% of the surface throughout the year.

3 Hydraulic condition is based on combination factors that affect infiltration and runoff, including (a) density and canopy of vegetative areas, (b) amount of year-round cover, (c) amount of grass or close-seeded legumes, (d) percent of residue cover on the land surface (good ≥ 20%), and (e) degree of surface roughness.

Poor: Factors impair infiltration and tend to increase runoff.

Good: Factors encourage average and better than average infiltration and tend to decrease runoff.

Agricultural Drainage Basics - Purpose of Ag Drainage

The US Environmental Protection Agency says:

"The purpose of agricultural drainage is to remove excess water from the soil in order to enhance crop production."

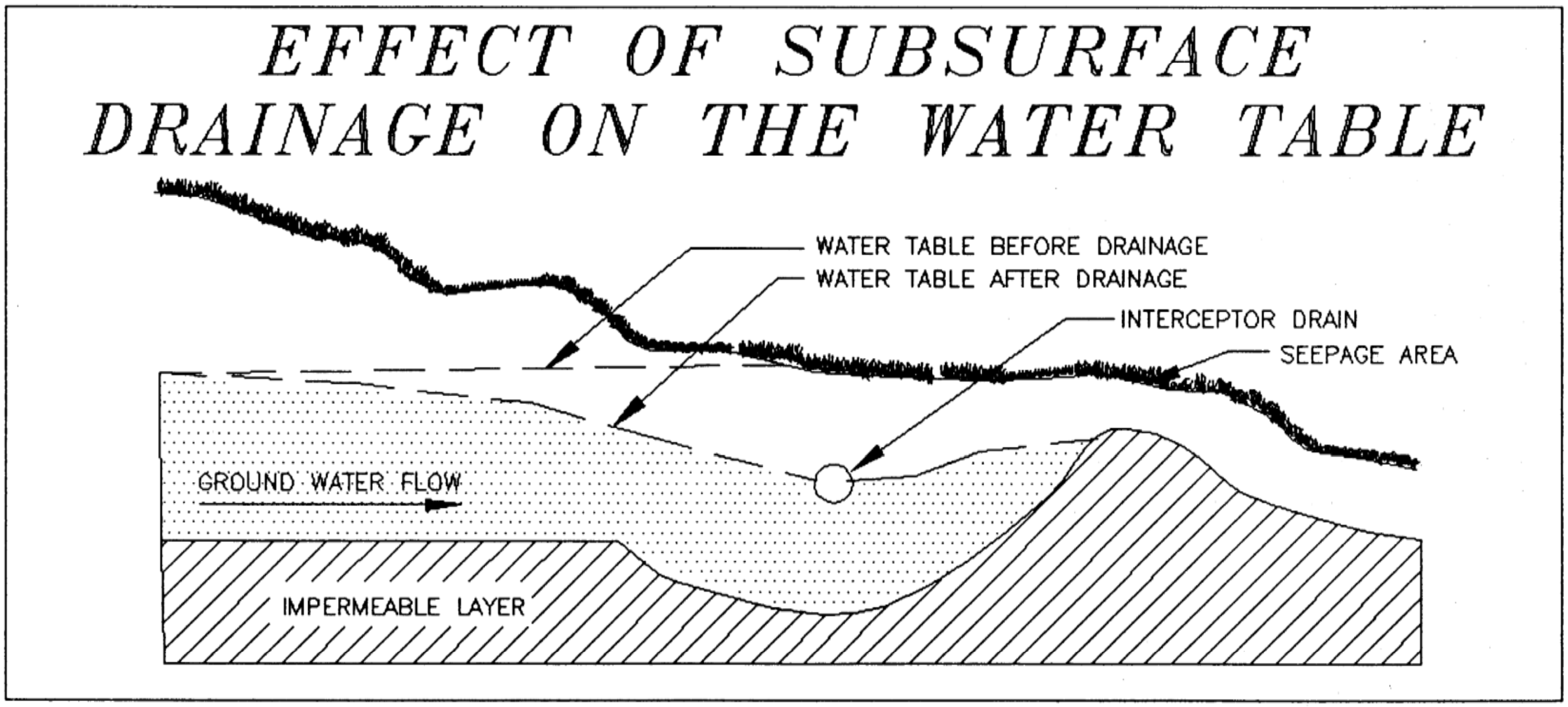
Agricultural Drainage Basics –
The Golden Rule Of Drainage

Drain only what is necessary for good soil conditions and crop growth …
and not a drop more. *R. Wayne Skaggs*

Agricultural Drainage Basics – Concerns About Drainage

1. *Increased loss of Nitrate and other soluble constituents.*
2. *Increased total runoff contributing to erosion and flooding downstream.*

Introduction To Subsurface Drainage Design – Controlling the In-Field Water Table



Source: USDA-SCS

Plate 3.28-2

Introduction To Subsurface Drainage Design – Design Flow Chart

Collect Background Information (soils, topo, crops, etc.)

Is Drainage Needed????? If no, then do not design.

Confirm Outlet – Capacity and Availability If no, then do not design.

Select Drainage Coefficient, Spacing, and Depth

Develop System Layout

Determine Grades and Depths

Determine Drain Sizes

Installation

Adapted from design by Gary Sands

Introduction To Subsurface Drainage Design – Layout

✓Common Tile Design

- Strategic/Get drains under wet spots.
  - Connect low spots with single tiles
  - Placed pattern tile laterals on grade (going downhill) and mains at the bottom of hill

Introduction To Subsurface Drainage Design – Layout (cont.)

Introduction To Subsurface Drainage Design – Layout (Cont.)

✓Best Tile Layout

- Still gets drains under wet spots.
  - Placed pattern tile laterals on contour and mains going down hill (on grade).

Introduction To Subsurface Drainage Design –

The Golden Rule of Drainage

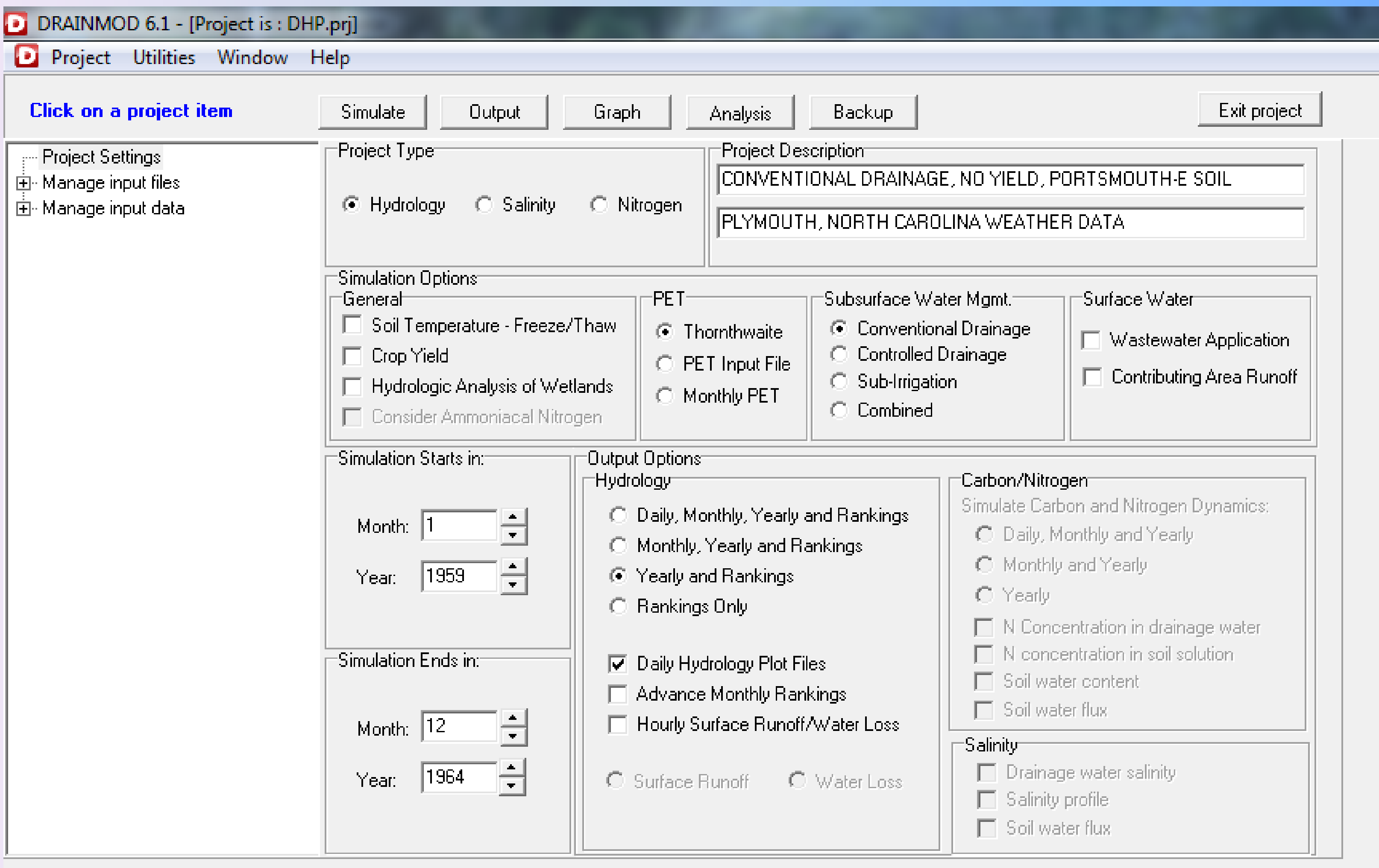
Drain only what is necessary for good soil conditions and crop growth …
and not a drop more. *R. Wayne Skaggs*

✓This is a risk tolerance issue for the producer!

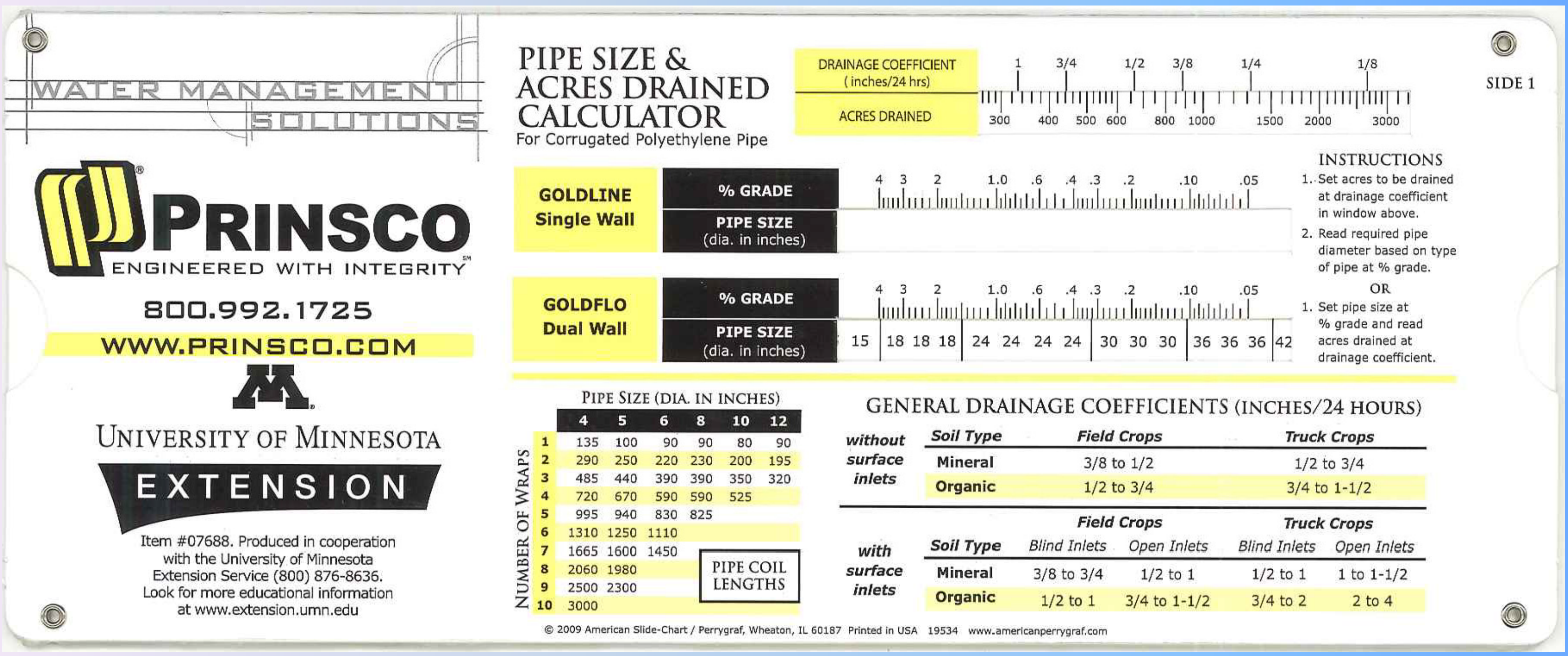
Introduction To Subsurface Drainage Design – Tools

- *DrainMod* - NCSU, Skaggs, etal.
- *Slide Calculator* – UMN, Prinsco
- *SDSU Drain Spacing Calculator - SDSU*

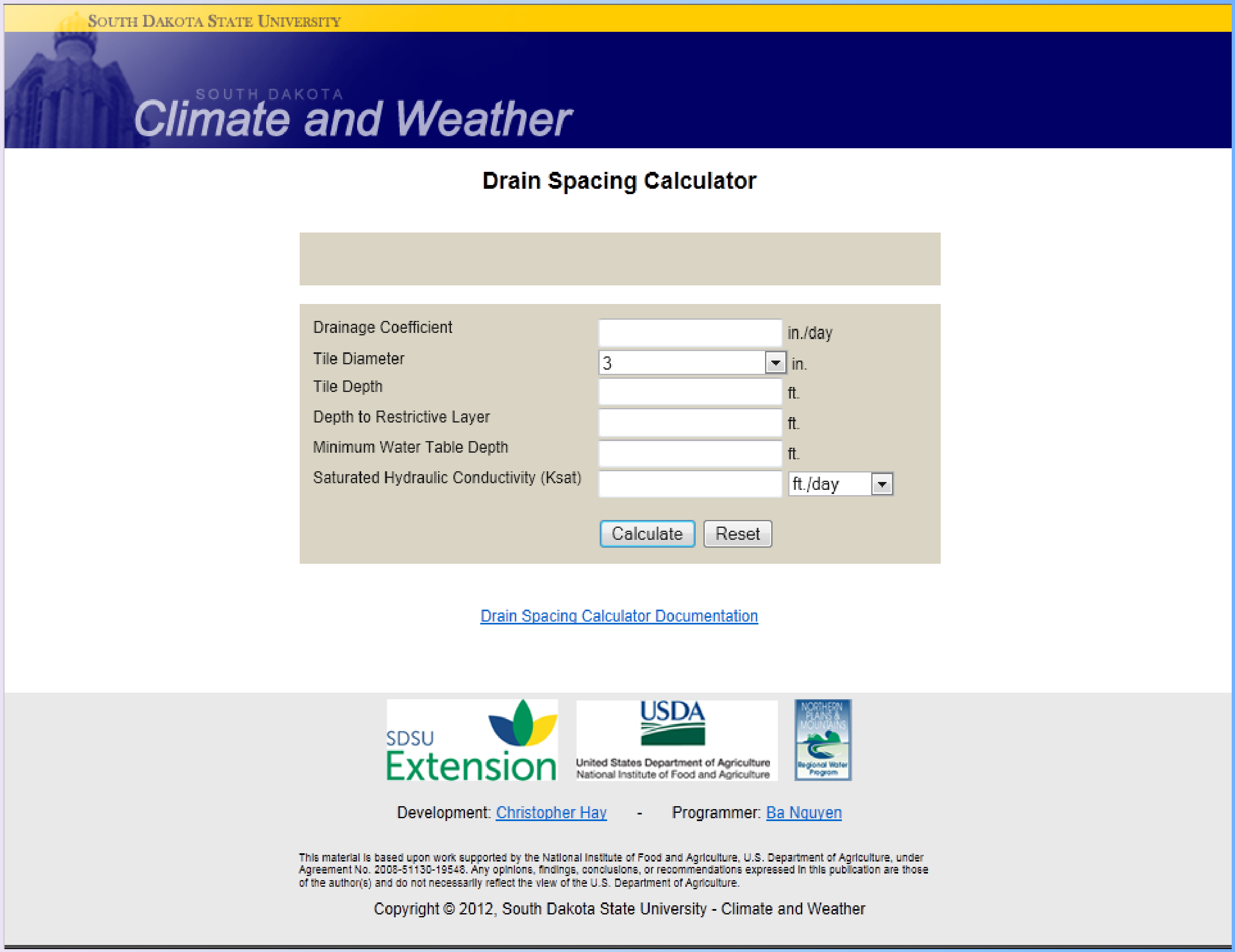
Introduction To Subsurface Drainage Design – Tools (Continued)



Introduction To Subsurface Drainage Design – Tools (Continued)



Introduction To Subsurface Drainage Design – Tools (Continued)



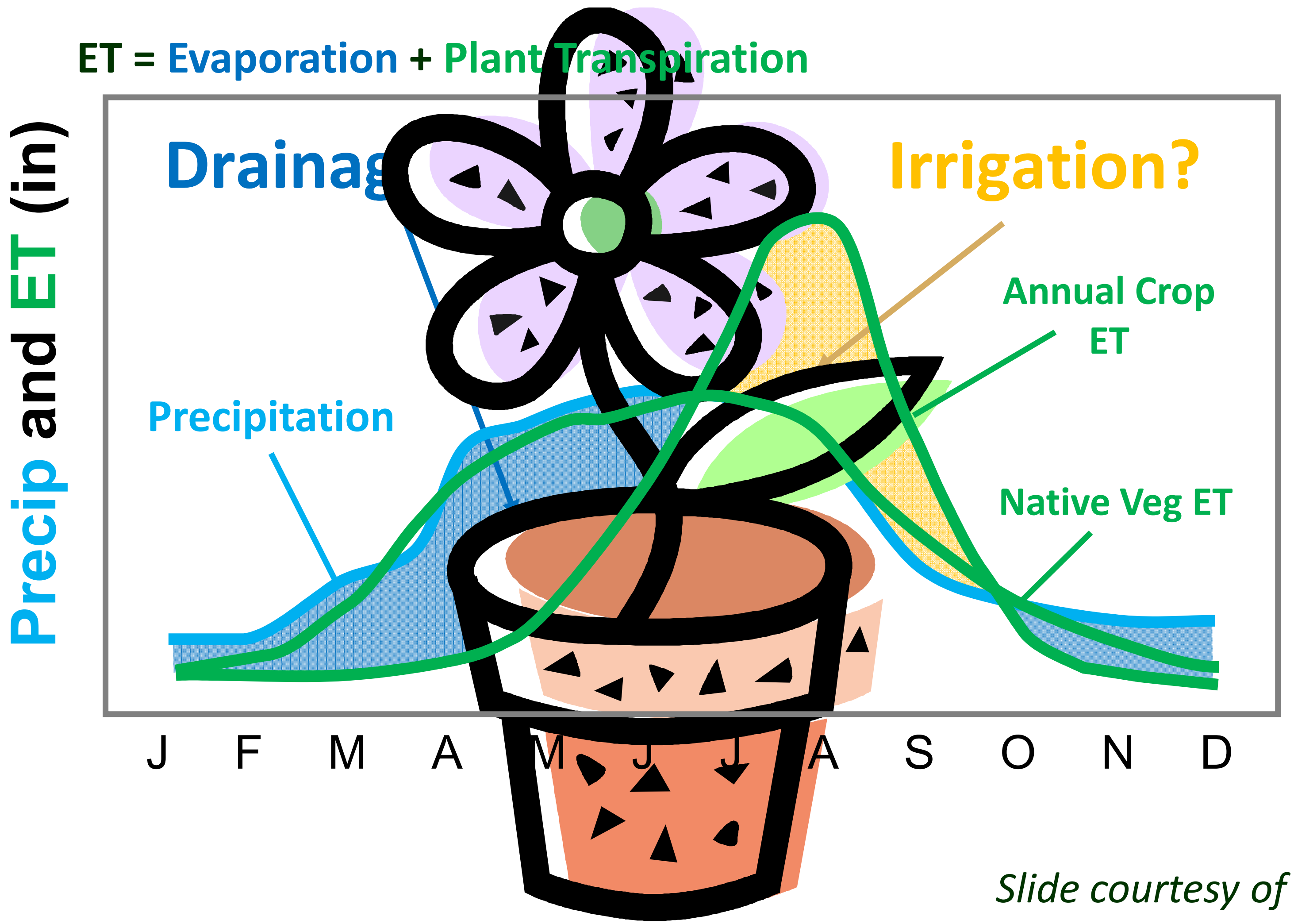
Introduction To Drainage Water Management (DWM) Design

Drainage Water Management is:

"the process of managing tile drainage water discharges from surface and/or subsurface agricultural drainage systems." (NRCS CP 554)

Water Management for Ag Production

Challenges & Opportunities



Slide courtesy of Dr. Gary Sands

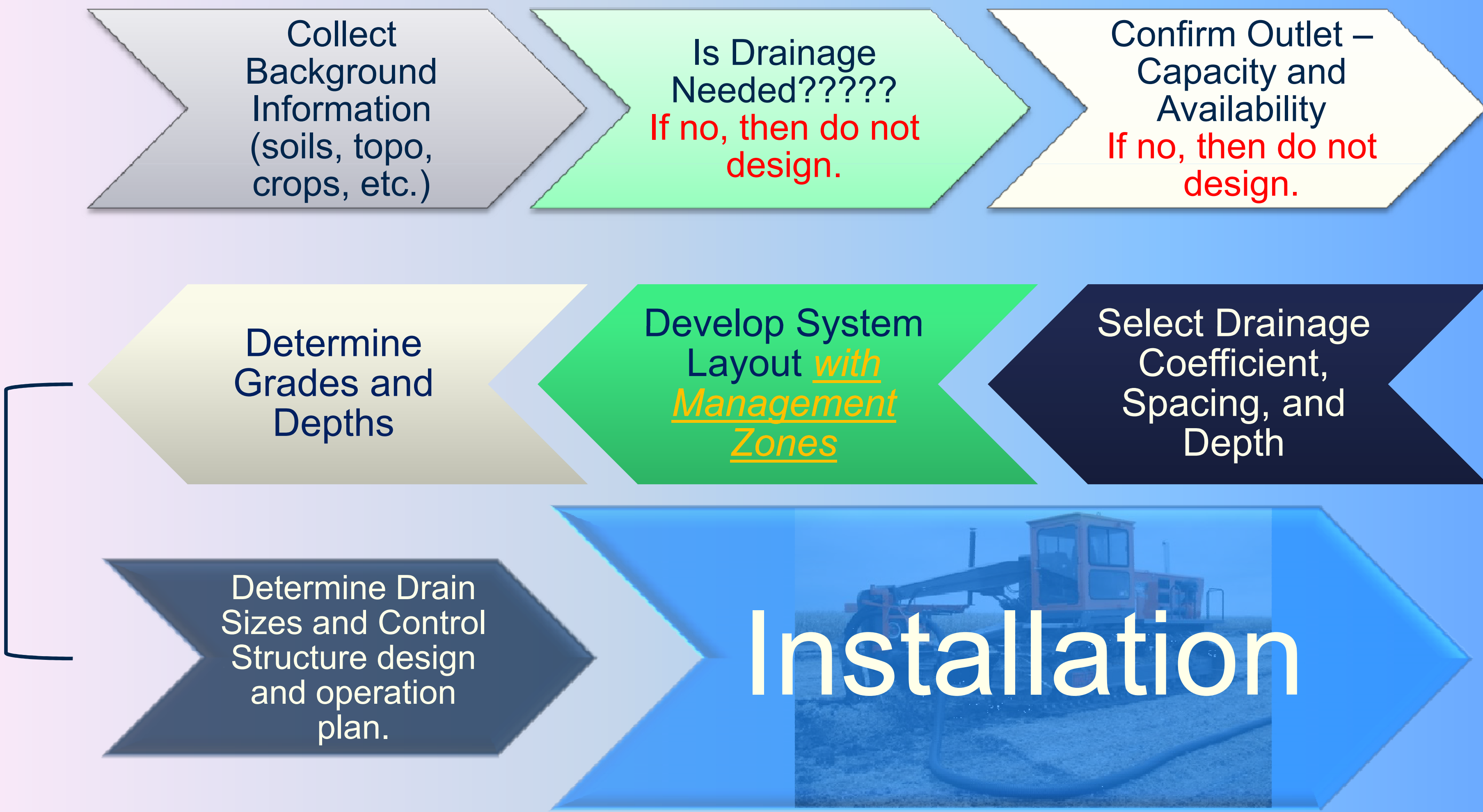
Introduction To Drainage Water Management (DWM) Design

Potential Benefits of Managing Tile Drainage:

1. Improve water quality by reducing nitrate loading to surface waters.
2. Improve the soil environment for vegetative growth.
3. Reduce the rate of soil matter oxidation.
4. Reduce wind and water erosion.
5. Enable seasonal soil saturation or shallow ponds.
6. Reduce drainage contribution to peak flows.

Adapted from DWM Plan Template

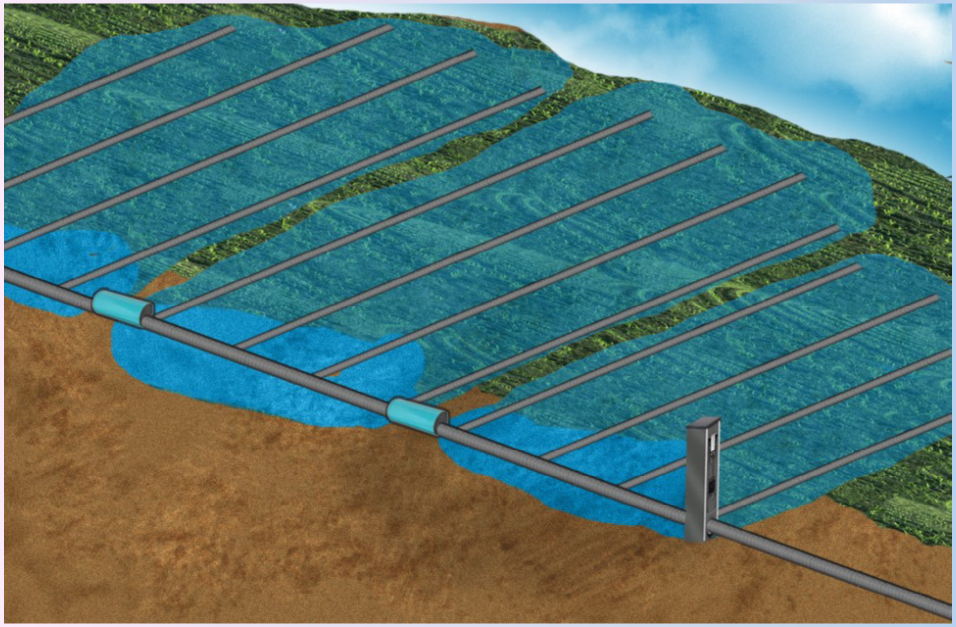
Introduction To Drainage Water Management (DWM) – Design Flow Chart

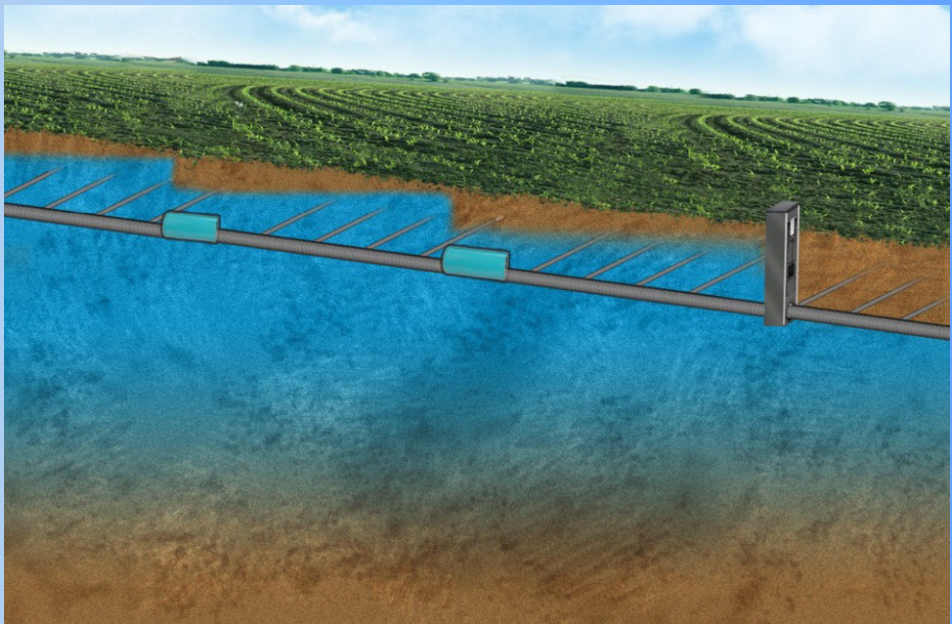


Adapted from design by Gary Sands

Introduction To Drainage Water Management (DWM) – Management Zones

Management Zones are an area in a field that are defined by the water table elevation change created by a Structure for Water Control installed on a subsurface drainage system.

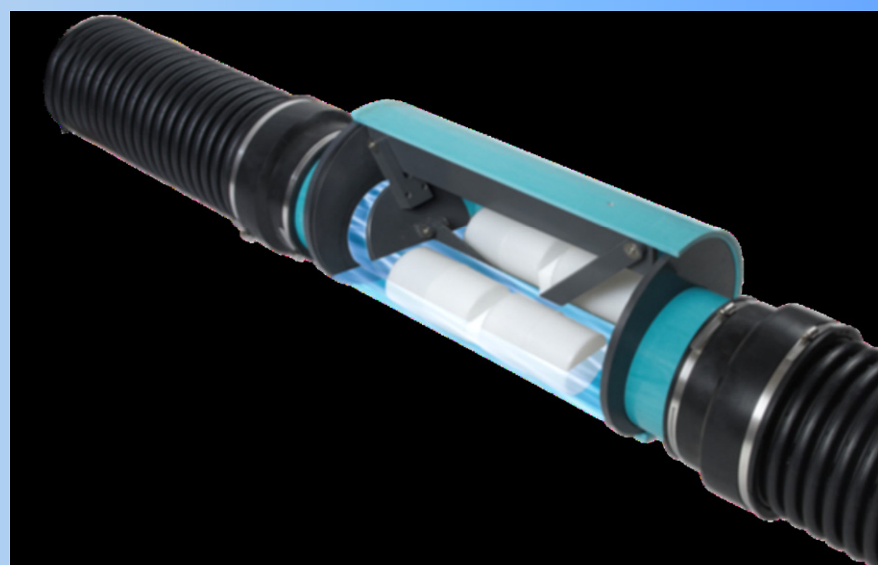




Graphics Courtesy of Agri Drain, Inc - www.agridrain.com

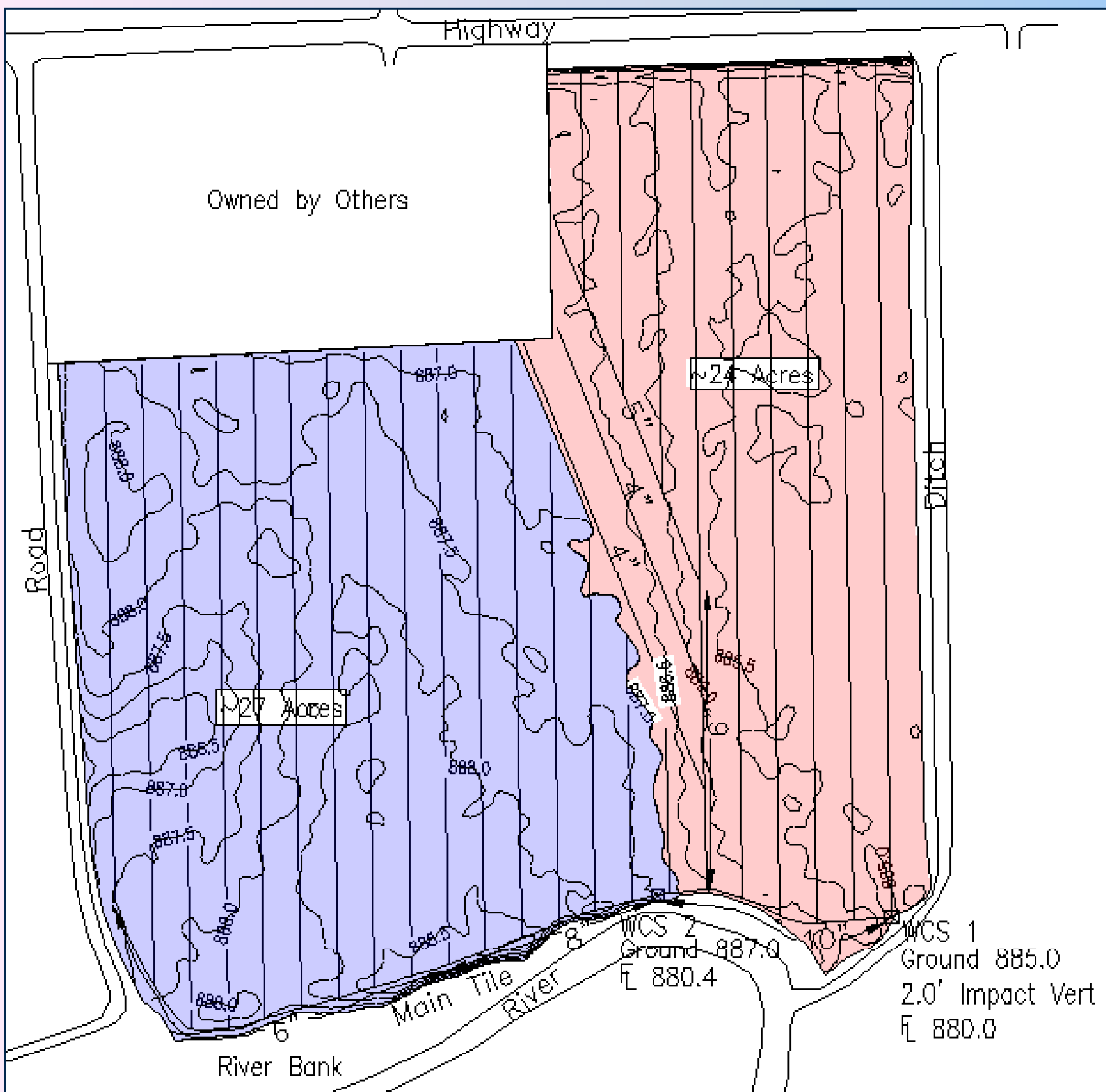
Introduction To Drainage Water Management (DWM) – Management Zones

Agri Drain^{tm} Stop Log Water Control Structure



Agri Drain^{tm} Water Gate Inline Water Control Structure

Introduction To Drainage Water Management (DWM) – Management Zones



- One field - two Management Zones.
- 51 acres controlled by two structures.
- Could use two different types of structures or two different elevation change settings in one type of structure.

Graphic from DWM Plan Example

Introduction To Drainage Water Management (DWM) – Considerations

1. Subsurface DWM works best on fields with slopes between 0 and 5%. (NRCS CP 554)
2. Design to manage drainage water with the least number of structures.
3. Decide feet of fall for DWM zones. 1.0 to 1.5 ft zone elevation change is optimum (2’ max to sell the practice.
4. Narrower spacing reduces the risk of yield loss due to excess wetness during the growing season.
5. When designing new systems put laterals at minimum grade on the contours and mains on the grade.

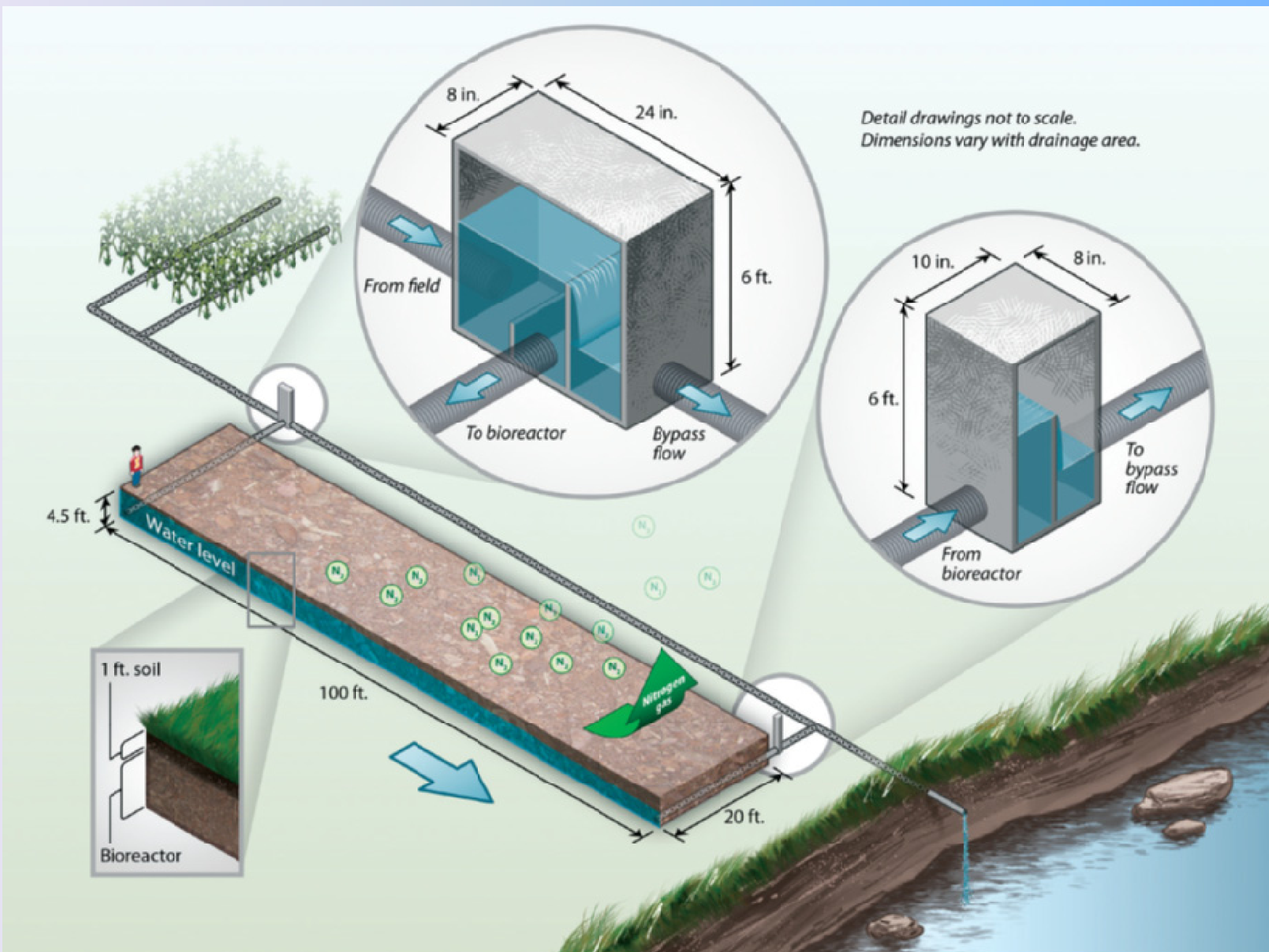
Introduction To Drainage Water Management (DWM) – Conservation Activity Plan (CAP)

CAP 130 DRAINAGE WATER MANAGEMENT PLAN

"The objective of Drainage Water Management (DWM) is to control soil water table elevations and the timing of water discharges from subsurface or surface agricultural drainage systems..."

From Minnesota CAP 130 Criteria

Added Attraction - CP 739 Interim Practice - Denitrifying Bioreactor



Descriptive illustration of a woodchip bioreactor (image by John Petersen, www.petersenart.com)

CP 739 Interim Practice - Denitrifying Bioreactor (cont.)

Denitrifying Bioreactors

- Are an edge-of-field practice to help remove nitrates that leach into tile drains.
- Consist of a non-porous plastic-lined trench filled with woodchips and covered with soil.
- Receive a portion of the tile water which is diverted to flow through the woodchips before entering surface water. A control structure determines the amount of tile flow that is diverted into the bioreactor. During periods of high flow, excess water bypasses the bioreactor and continues to flow through the existing field tile.
- Create a gathering place for micro-organisms from the soil and tile water that colonize the woodchips.
  - Some of them break down the woodchips into smaller organic particles.
  - Other micro-organisms "eat" the carbon produced by the woodchips, and "breathe" the nitrate from the water. Just as humans breathe in oxygen and breathe out carbon dioxide, these microorganisms breathe in nitrate and breathe out nitrogen gas, which exits the bioreactor into the atmosphere.
- Through this process, nitrate is removed from the tile water before it can enter surface waters.
- The bioreactor has no adverse effects on crop production and is designed in a way that it does not restrict drainage.

CP 739 Interim Practice - Denitrifying Bioreactor (cont.)

"… bioreactors ***in Illinois*** (italics mine) have cut nitrate flows significantly, Cooke says. "During ordinary flow periods, more than 60% of the nitrate is removed from tile drains." *The Farmer Magazine, 11-25-11*

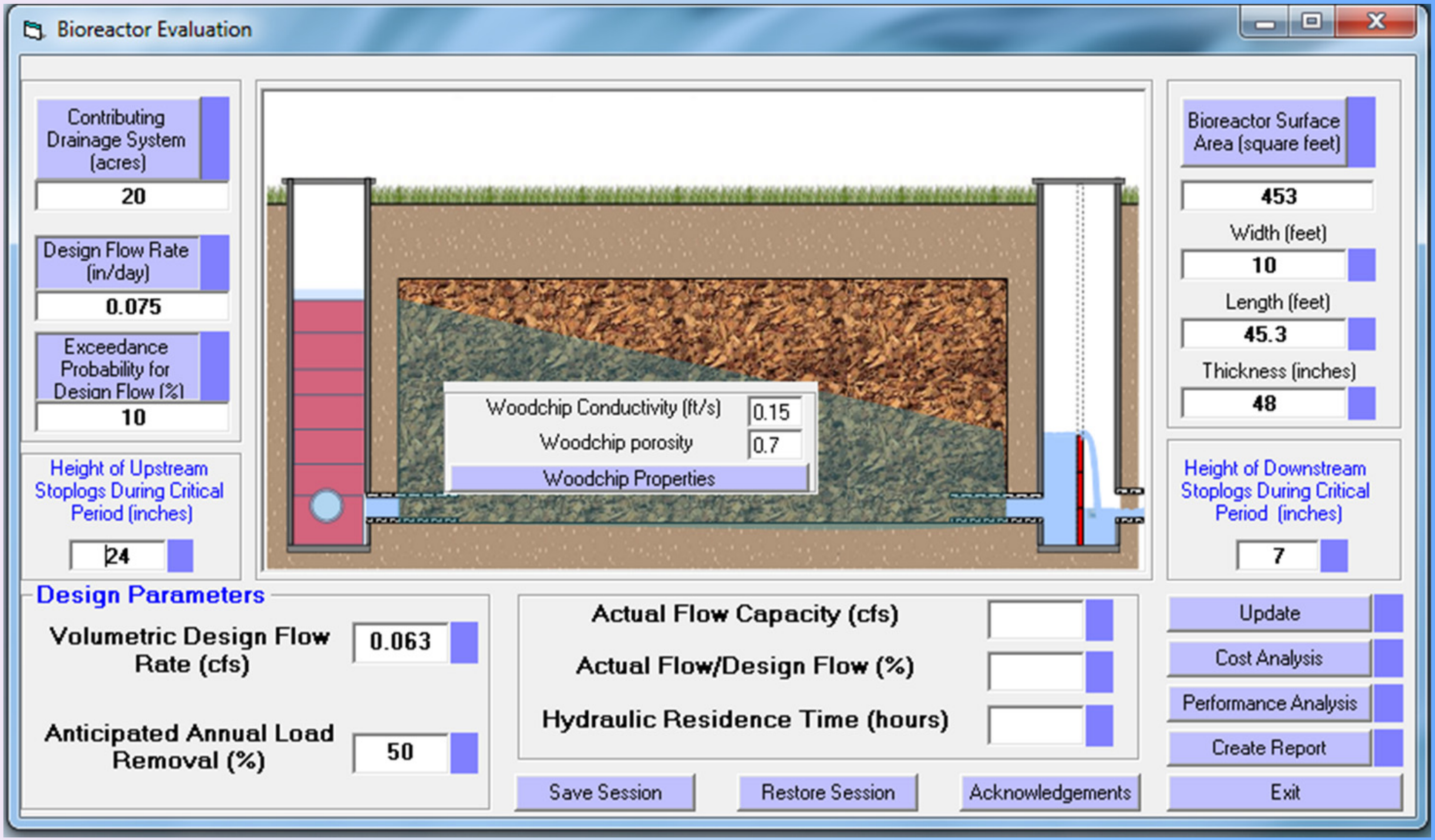
"Iowa State University water resources engineer Matt Helmers says woodchip bioreactors can remove from 15% to 60% of the annual load of nitrate from drainage water in tile lines. Helmers says there's still much to be learned about bioreactors and how to maximize their performance." *Corn and Soybean Digest, 3-1-08*

CP 739 Interim Practice - Denitrifying Bioreactor (cont.)

- Design Methods have been put forth by both the University of Illinois and Iowa State University.
- These processes have been refined as new data has become available.

CP 739 Interim Practice - Denitrifying Bioreactor (cont.)

University of Illinois



CP 739 Interim Practice - Denitrifying Bioreactor (cont.)

Iowa State University

Subsurface Drainage Bioreactor Design

Developed by M. Helmers and L. Christianson, ABE Iowa State Unviersity

Instructions: Enter values in gray cells

Field Information:		**Explanatory Notes:**
Tile Size (in)	8	Known from site
Tile Grade (%)	0.3	Known from site
Dual Wall	no	no
Velocity in Pipe (ft/s)	1.65	Mannings Gravity Driven Flow Equation = $1.49 \times \sqrt{\left(\frac{Tile Grade}{100}\right)} \times \frac{\left(\frac{Tile Size}{(Conversion)}\right)^{\frac{2}{3}}}{0.012 (for\ dual\ wall) OR\ 0.015 (for\ non-dual\ walled)}$
Peak Flow from Tile Size (cfs)	0.5752	Flow rate = Velocity x Area of Tile
Media Information:		
Conductivity of Wood Media (ft/s) (K)	0.31168	Converted from 9.5 cm/s to ft/s; value determined in Porous Media Lab, ABE-ISU
Porosity of Wood (ρ)	0.7	Taken from van Driel et al., 2006
Bioreactor Inputs and Calculations:		
Flow Length (ft) (L)	80	Iteratively choose
Trench Width (ft) (W)	12	Iteratively choose
Inlet height (ft)	3	Iteratively choose
Outlet height (ft)	2	Iteratively choose
Head Drop (ft) (ΔH)	1	Calculated based on diffference between inlet and outlet
Flow Depth (ft) (d)	2.5	Calculated to be in bioreactor middle (average of inlet and outlet height)
Hydraulic Gradient (i)	0.0125	Head Drop / Flow Length
Results:		
Bioreactor Flow Rate (cfs) (Q)	0.12	Darcy's Law for Porous Media Flow = $Hyd. Conductivity \times Hyd. Gradient \times Flow\ Area = KiA = Ki(W \times d)$
Hydraulic Retention Time (hours) (HRT)	**3.99**	HRT = $\tau = \frac{Volume \times porosity}{Flow\ rate} = \frac{V\rho}{Q} = \frac{l \times w \times d \times \rho}{Q}$ (conversions included)
% of peak flow that can be passed through bioreactor	**20.32**	Bioreactor Flow Rate / Peak Flow from Tile

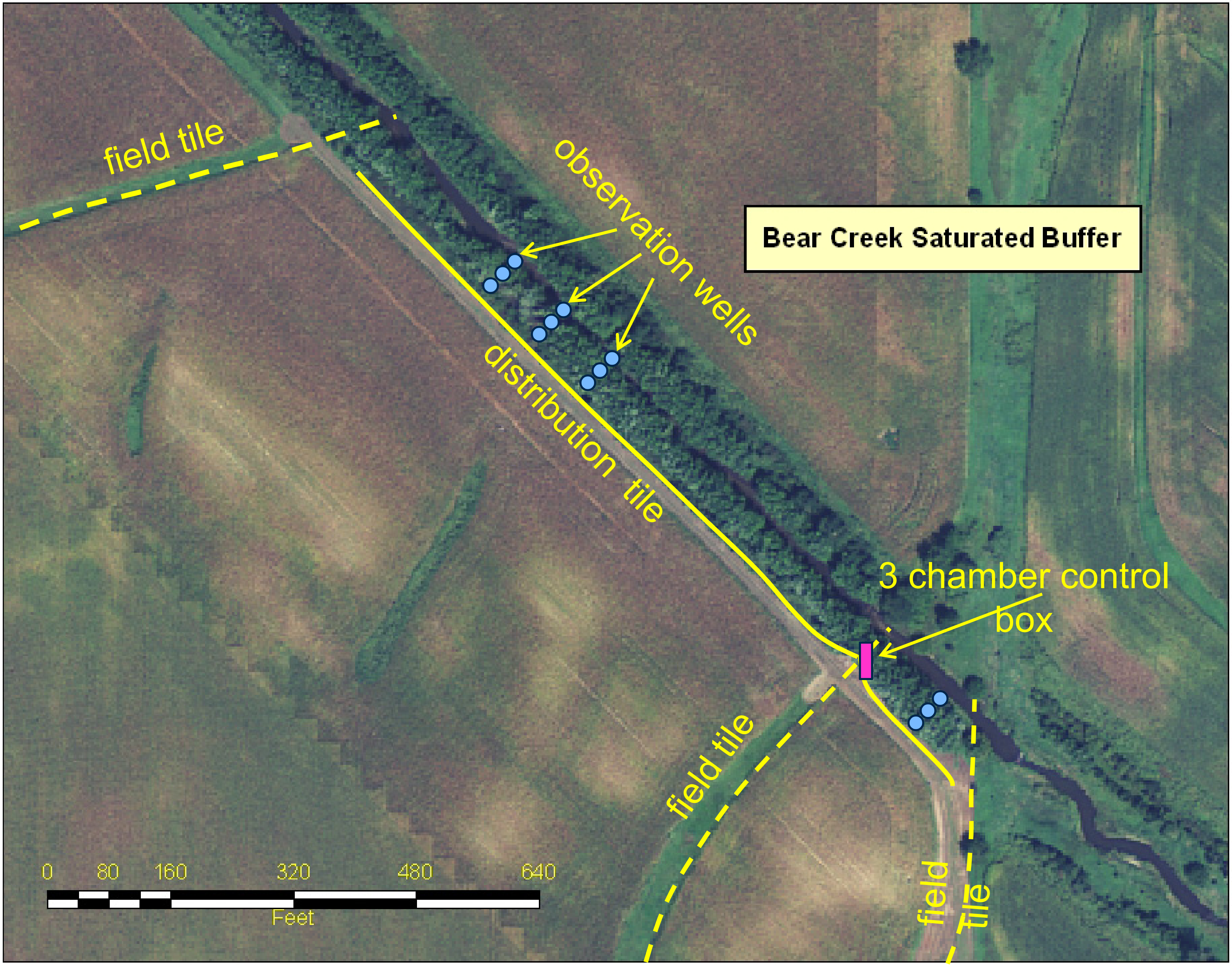
Bioreactors are designed to treat approximately 20% of the peak flow rate.
The design retention time is between 4 - 8 hours (Robertson et al., 2000; van Driel et al., 2006; Christianson et al., 2011).

For More Information Check Out This Website:

https://engineering.purdue.edu/watersheds/conservationdrainage/bioreactors.html

New Conservation Practice – Vegetated Subsurface Drain Outlet

- aka "**Saturated Buffer**"
- Interim Conservation Practice Standard 739
- First demonstration by Iowa State University starting in 2011 along Bear Creek
- First demonstration in Minnesota near Granite Falls on Doug Albin farm – fall 2012
- ADMC has a Conservation Innovation Grant for 3 demo sites each in IA, IL and IN



Courtesy of Dr. Dan Jaynes, USDA-ARS, Iowa State University

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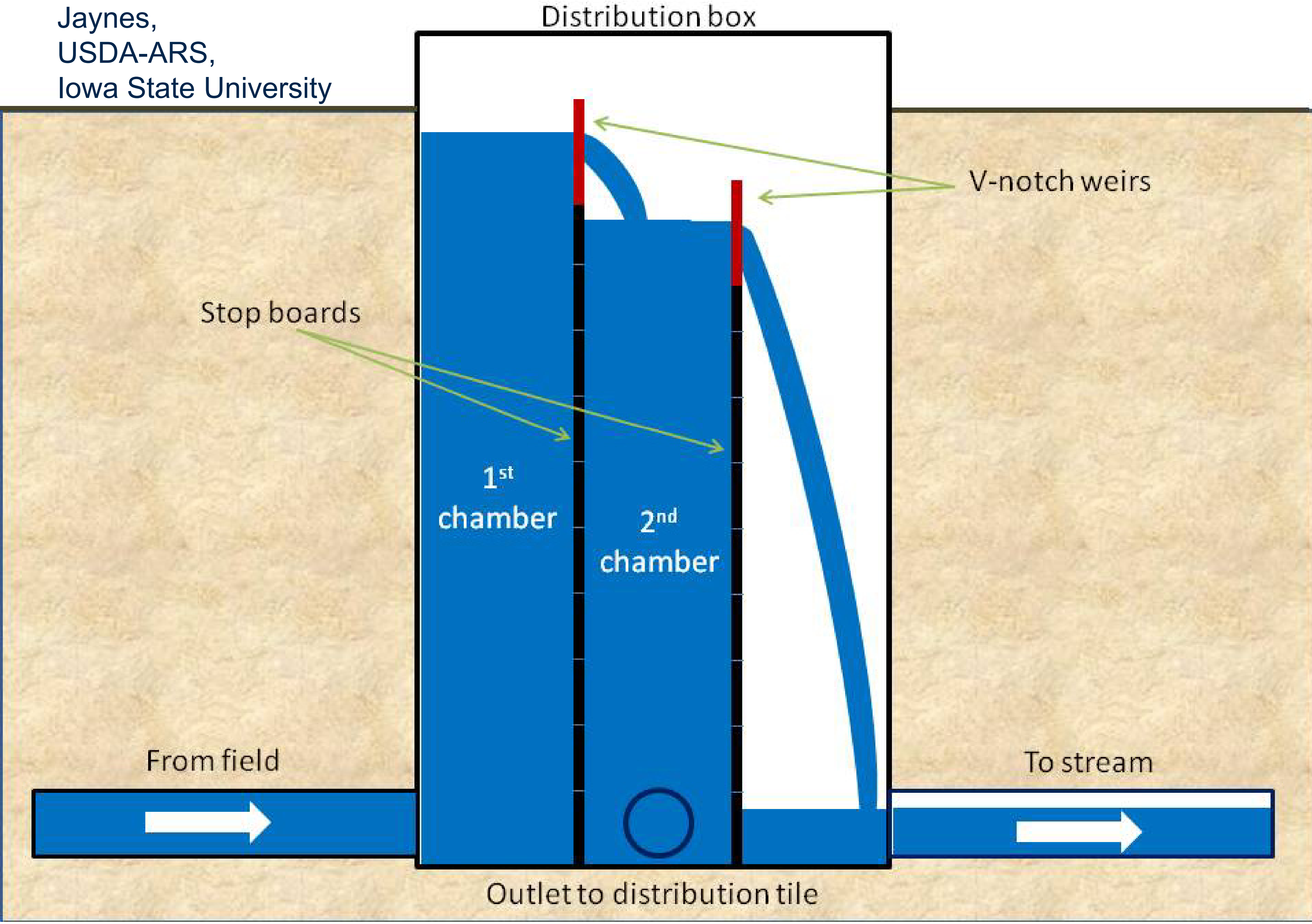
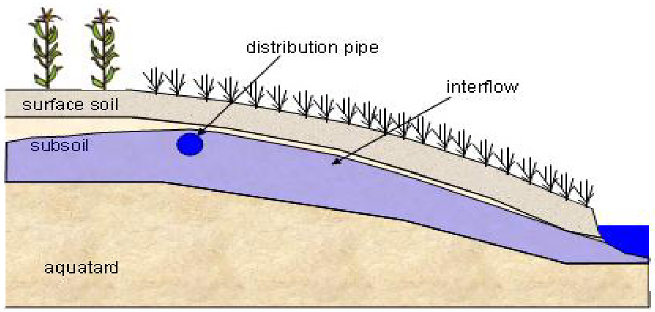
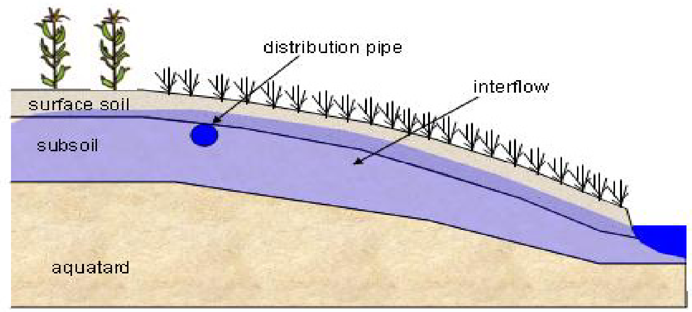


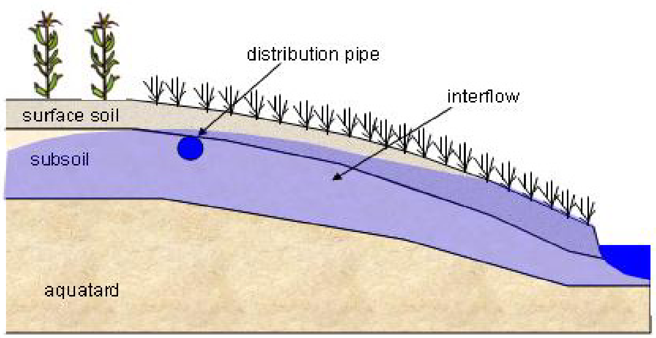
Induced Seepage Flow Effects and Considerations



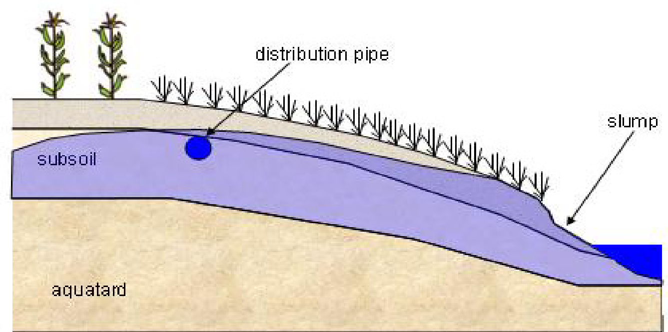
a) Enhanced uptake



b) Enhanced denitrification



c) Surface discharge



d) Channel slumping?

Courtesy of Dr. Dan Jaynes, USDA-ARS, Iowa State University