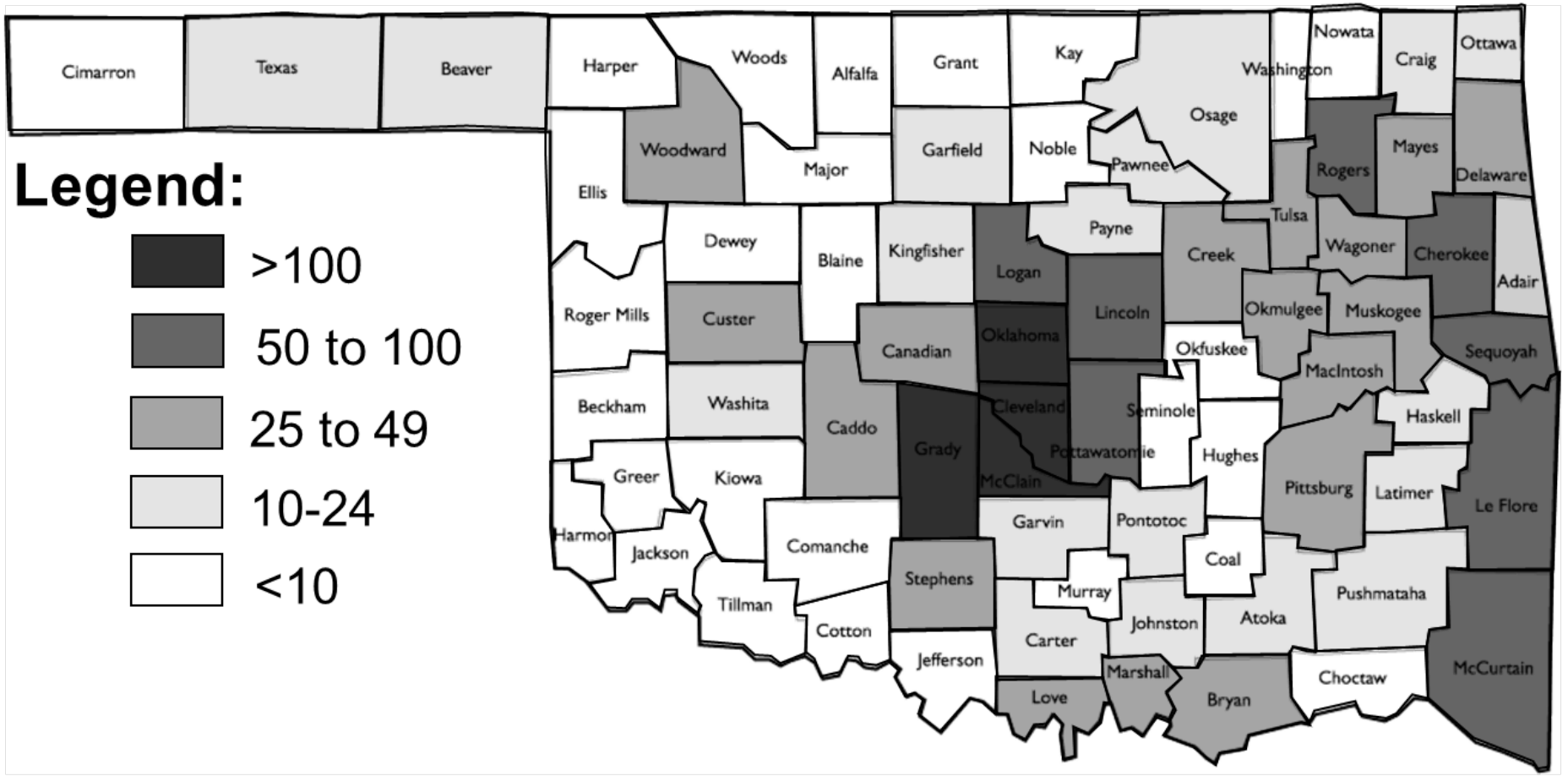
Using Modelling to Assess Septic System Regulations

Sergio Abit and Joshua Maples

Introduction

- Approximately 19% of homes in U.S. rely on Onsite Wastewater Treatment Systems (OWTS) for disposal and treatment of domestic waste (United States Census Bureau, 2015).
- In Oklahoma, 40% (Department of Environmental Quality, 2016).
  - In 2017, 9,419 single-unit houses were built in Oklahoma. That year around 40% of all septic systems installed in the state are conventional systems. (Abit, 2019).

Density of Newly Installed Conventional Systems in OK



Based on most recent three-year average (2015-2017)

Source: Oklahoma DEQ

Introduction

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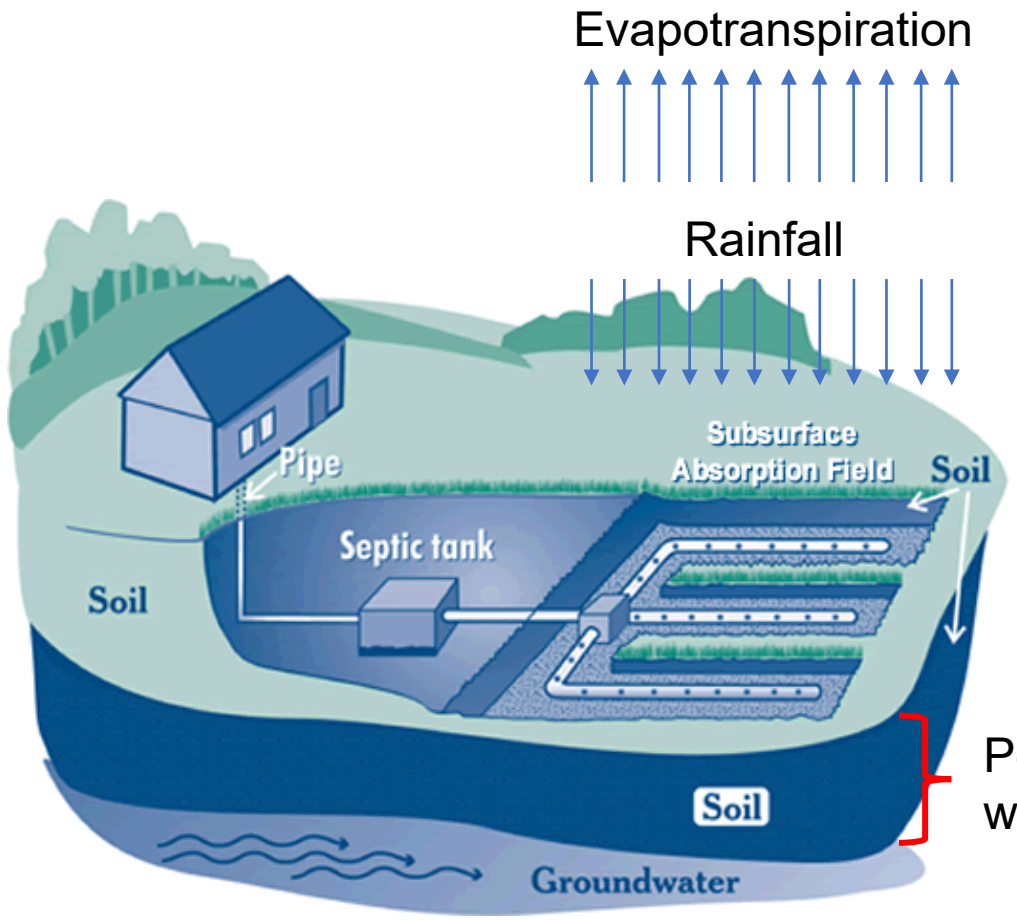
- In Oklahoma, 40% (Department of Environmental Quality, 2016).
  - In 2017, 9,419 single-unit houses were built in Oklahoma. That year around 40% of all septic systems installed in the state are conventional systems. (Abit, 2019).
- Current regulation for sizing of conventional OWTS ignore the climate gradient across the state. – **We have one set of rules that applies to the entire state.**

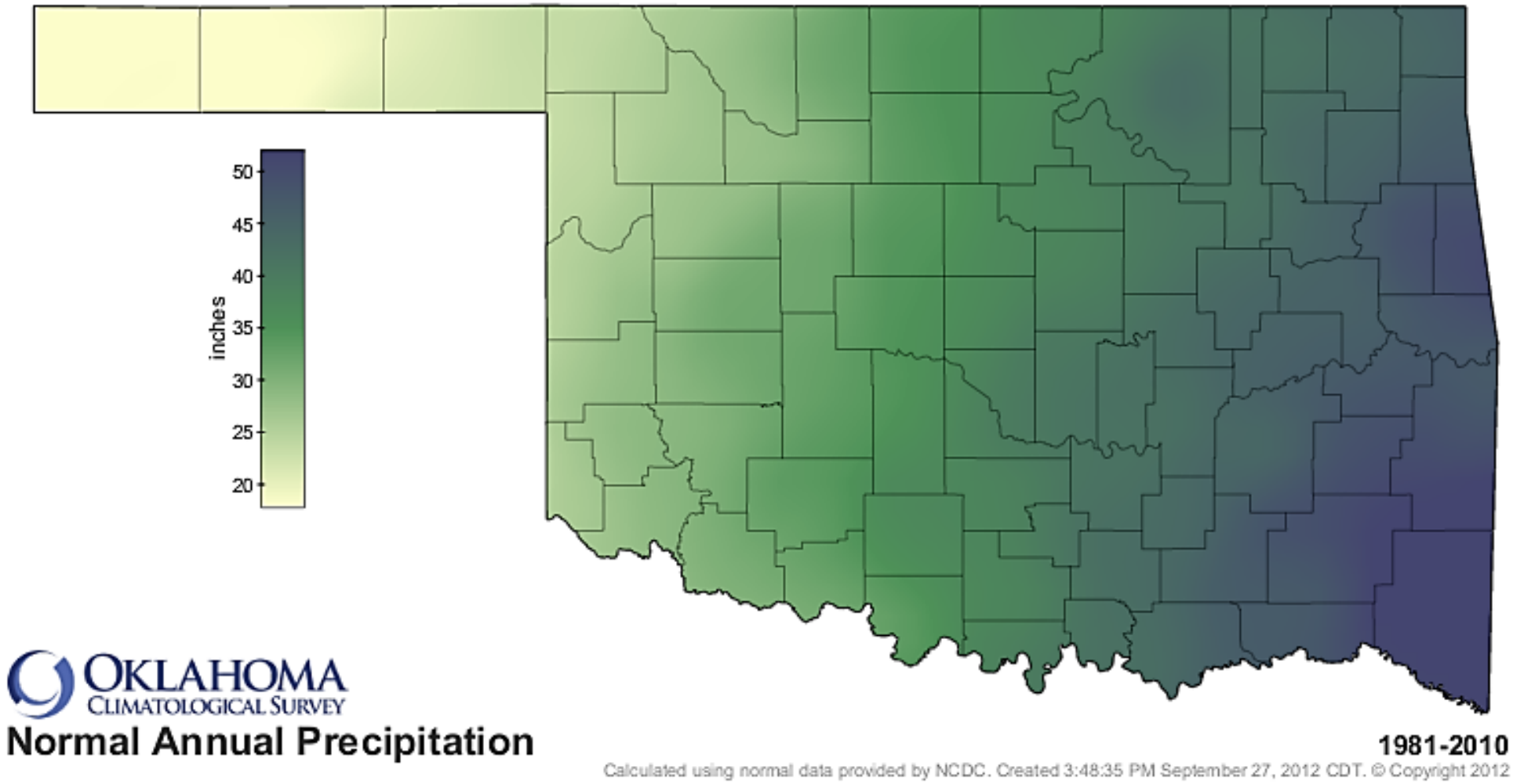
Influence of Climate factors



Performance is affected by quantity of water that need to be treated

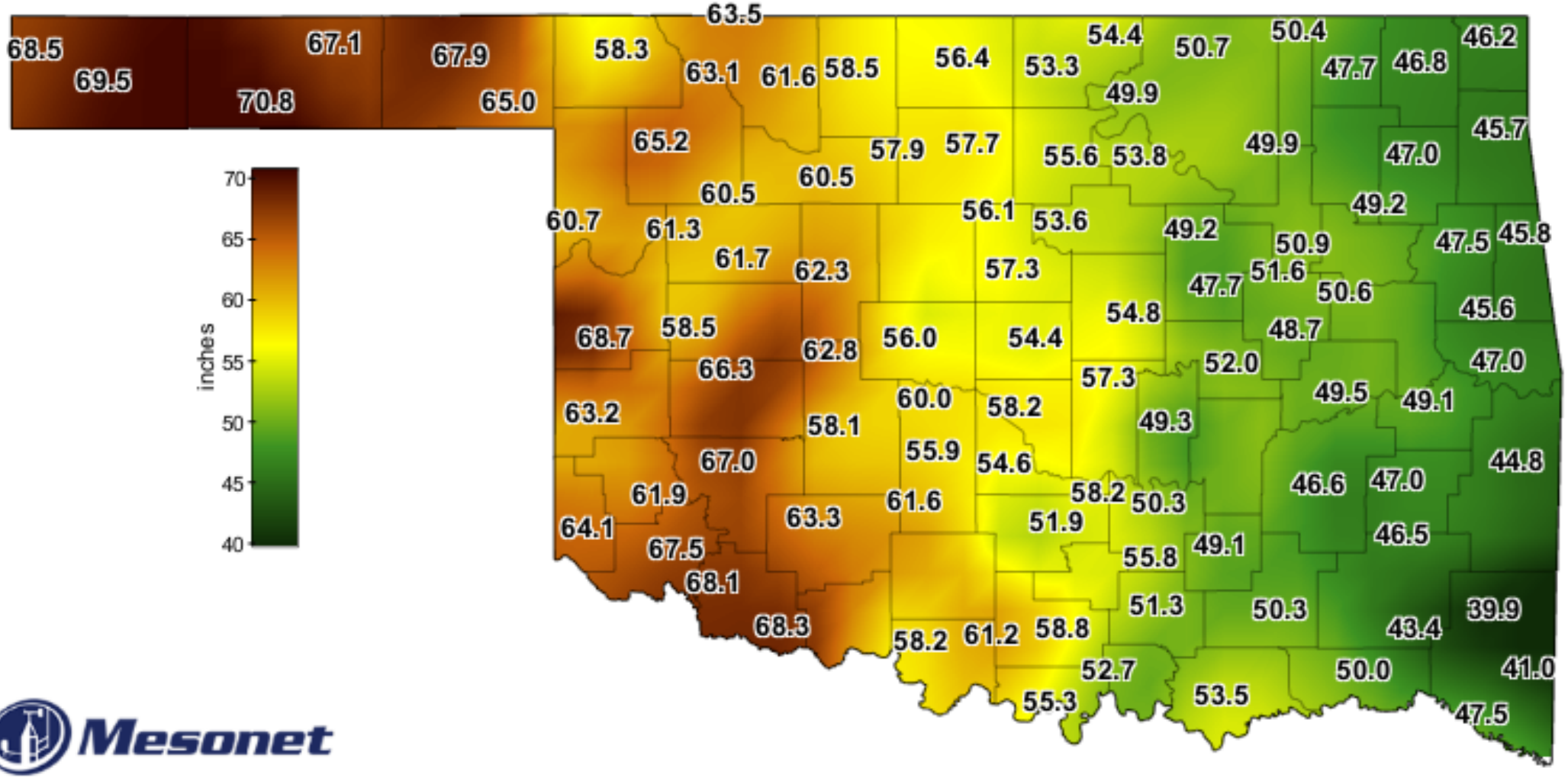
Conventional System Maintenance. Reprinted from Oklahoma Department of Environmental Quality. Retrieved December 12, 2018, from http://www.deq.state.ok.us/eclsnew/OnSite/system_maintenance/Conventional.html. Copyright 2015 from Oklahoma Department of Environmental Quality.

Rainfall Variability in Oklahoma



Normal Annual Precipitation 1981-2010. Reprinted from Oklahoma Climatological Survey. Retrieved December 12, 2018, from http://climate.ok.gov/index.php/climate/map/normal_annual_precipitation/oklahoma_climate. Copyright 2012 from Oklahoma Climatological Survey.

Evapotranspiration Variability in Oklahoma



Mesonet

Total Potential Evapotranspiration, Short Crop

Full Year 2004-2018

Created 4:09:23 PM October 16, 2019 CDT. © Copyright 2019

Total Potential Evapotranspiration 2004-2018. Reprinted from The Oklahoma Mesonet. Retrieved October 16, 2019, from http://www.mesonet.org/index.php/weather/mesonet_averages_maps#y=average&m=ann&p=pets&d=false. Copyright 2019 from The Oklahoma Mesonet..

Oklahoma DEQ Regulations

- Separated by soil type and number of bedrooms per residence
- Uniform across the state
- Study focused on soil groups 2, 3, & 4:
  - Loamy Sand, Loam, and Clay Loam

Minimum Trench Length in Meters

Soil Group	Number of Bedrooms In Residence			
	Two or Fewer	Three	Four	Each Additional Bedroom
1	Prohibited			
2	49	64	79	15
2a	76	101	125	24
3	104	137	168	30
3a	152	203	253	50
4	183	268	335	67
5	Prohibited			

Minimum Trench Length in Meters. This table shows the sizing requirement for septic systems based on soil groups and number of bedrooms in linear length.

Kansas Department of Health and Environment Regulations

- Very similar to Oklahoma's rules
- Very similar climate
- Recommend sizing reductions across the state climate gradient

Recommended Absorption Reductions

	Western Kansas	**Central Kansas**	**Eastern Kansas**
Actual absorption area (in percent)	65	80	100
Recommended reduction (in percent)	35	20	0

Table 2. Recommended Absorption Reductions. Reprinted State of Kansas Department of Health and Environment. Retrieved December 13, 2018, from http://www.kdheks.gov/nps/resources/mf2214.pdf. Copyright 1997 from State of Kansas Department of Health and Environment.

Why Recommend Adjustments?

- Size Reduction
  - Cost – linear length in pipe; labor; installation
  - Space – reduced soil disturbance; fit smaller lot sizes

- Size Increase
  - Effectively treat the wastewater effluent
  - Prevent septic system backflow

Objective Statement

- Assess the hydraulic performance associated with the current regulations for the sizing of conventional on-site wastewater treatment systems across a climate gradient.
- Evaluate the hydraulic effects of potential reductions in STA sizes for different soil groups under various precipitation regimes across the climate gradient of Oklahoma.

Methods

- Weather data:
  - 9 climate divisions

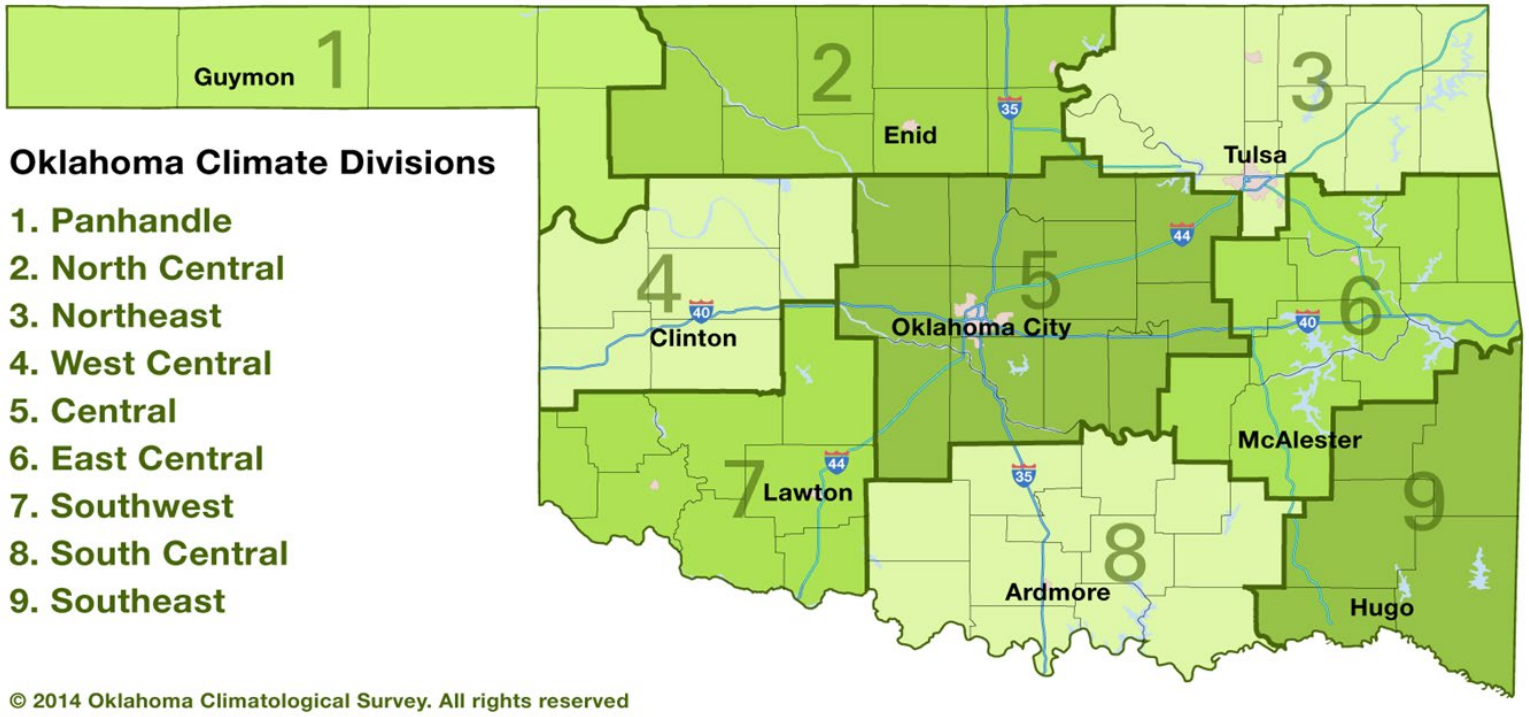


Figure 3. Map of Oklahoma Climate Divisions. Reprinted from Oklahoma Climatological Survey. Retrieved December 12, 2018, from http://climate.ok.gov/index.php/climate/map/map_of_oklahoma_climate_divisions/oklahoma_climate. Copyright 2014 from Oklahoma Climatological Survey.

Methods

- Weather data:
  - 9 climate divisions
  - One weather station per division
    - Centrally located
    - Sufficient amount of data
  - 1998-2017
    - 20 years (7,305 days)

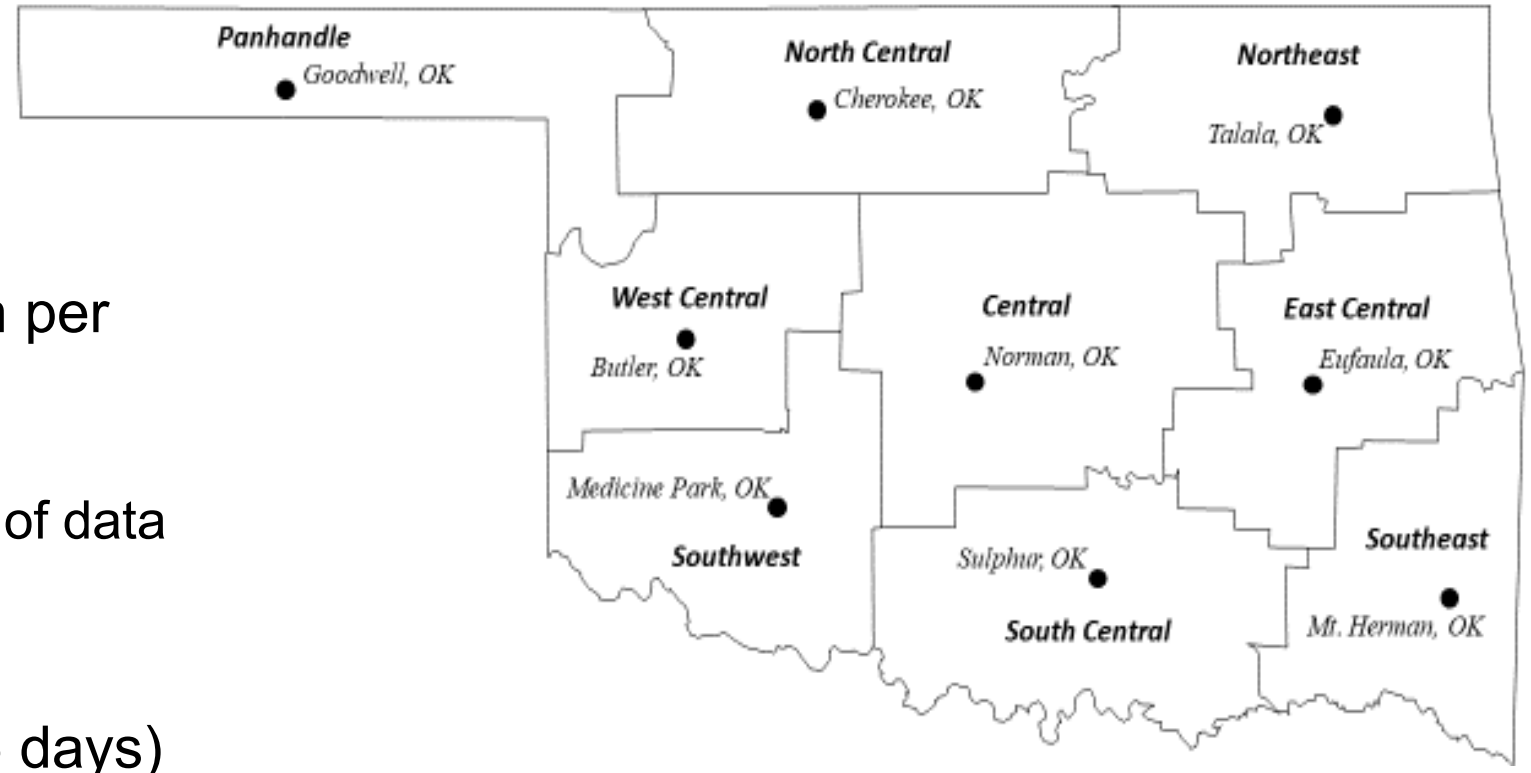
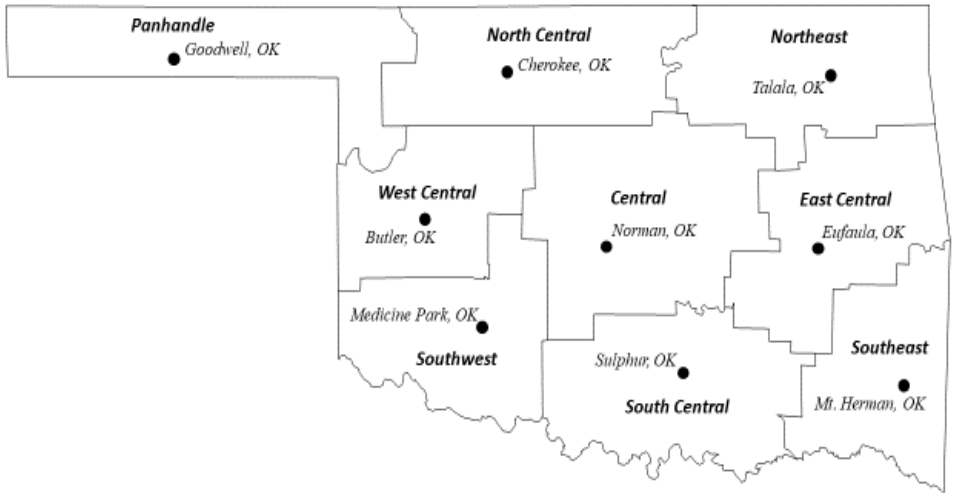


Figure 4. Map of Oklahoma climate divisions and selected Mesonet weather stations used for modeling conventional septic system sizing requirements.

Methods

www.mesonet.org



Methods

Hydrus-1D

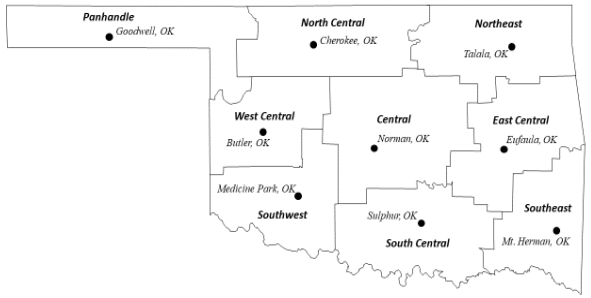
- Customized by Dr. Simunék
- Allowed subsurface water source

- Soil water flow simulations: <u>270 Total Modeled Scenarios; 20 years (7,305 days)</u>

Soil 2 – Loamy sand
Soil 3 – Loam
Soil 4 – Clay Loam

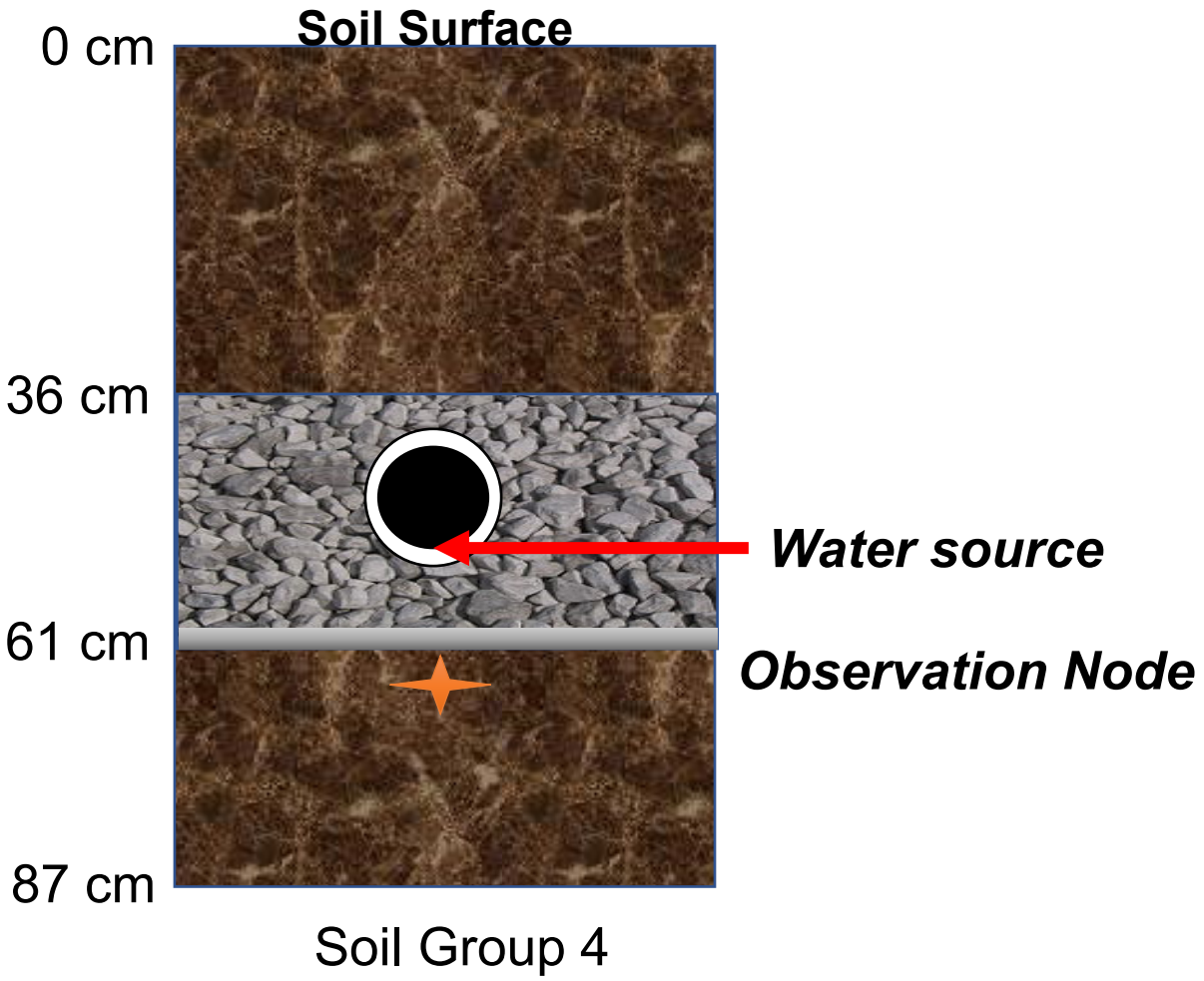
Bare
Year-round grass

9 climate divisions x 3 soil classes x 5 size adjustments x 2 surface treatments



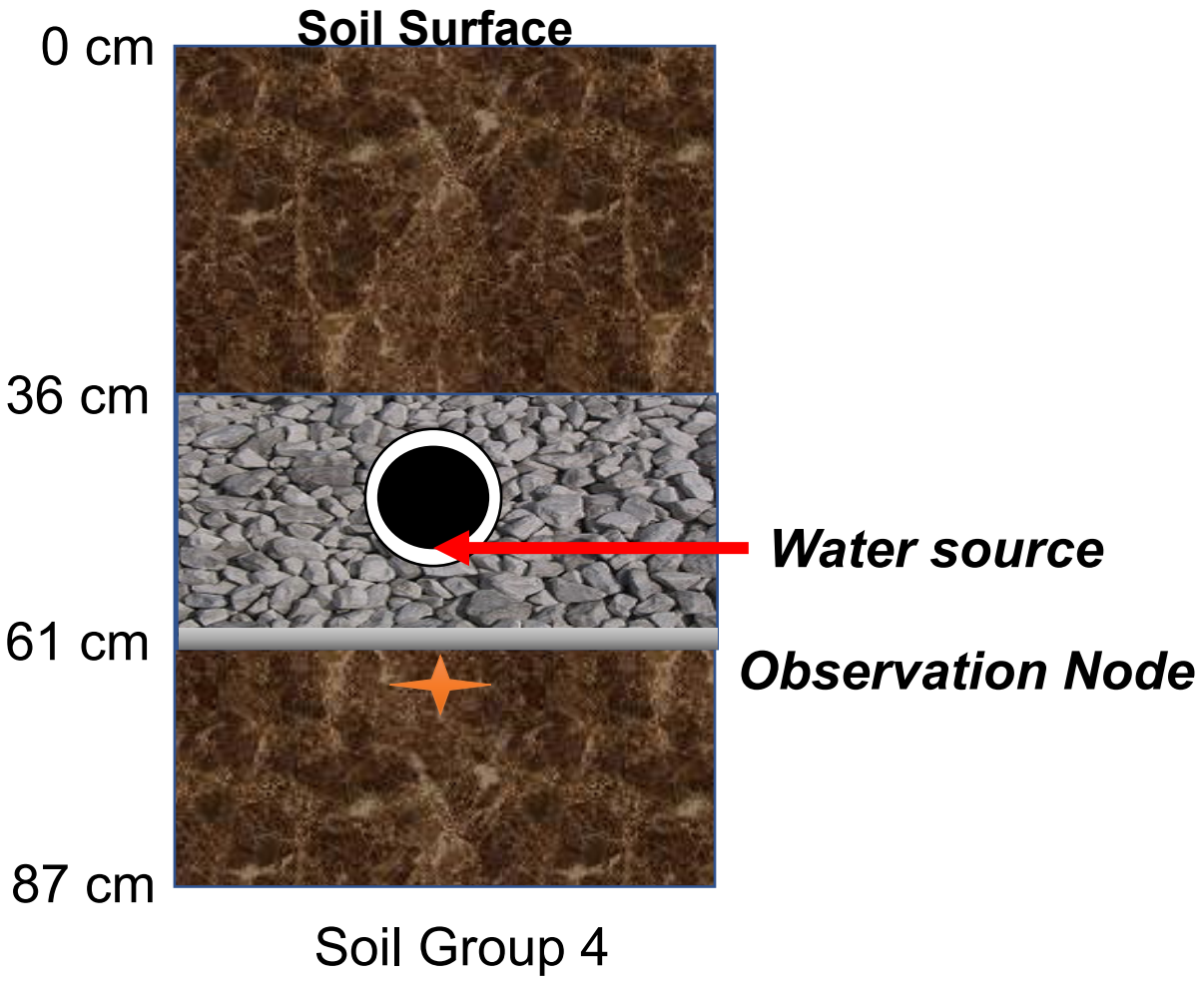
Sized to regulations
10% Reduction
20% Reduction
30% Reduction
40%Reduction

HYDRUS 1D – Soil Profile



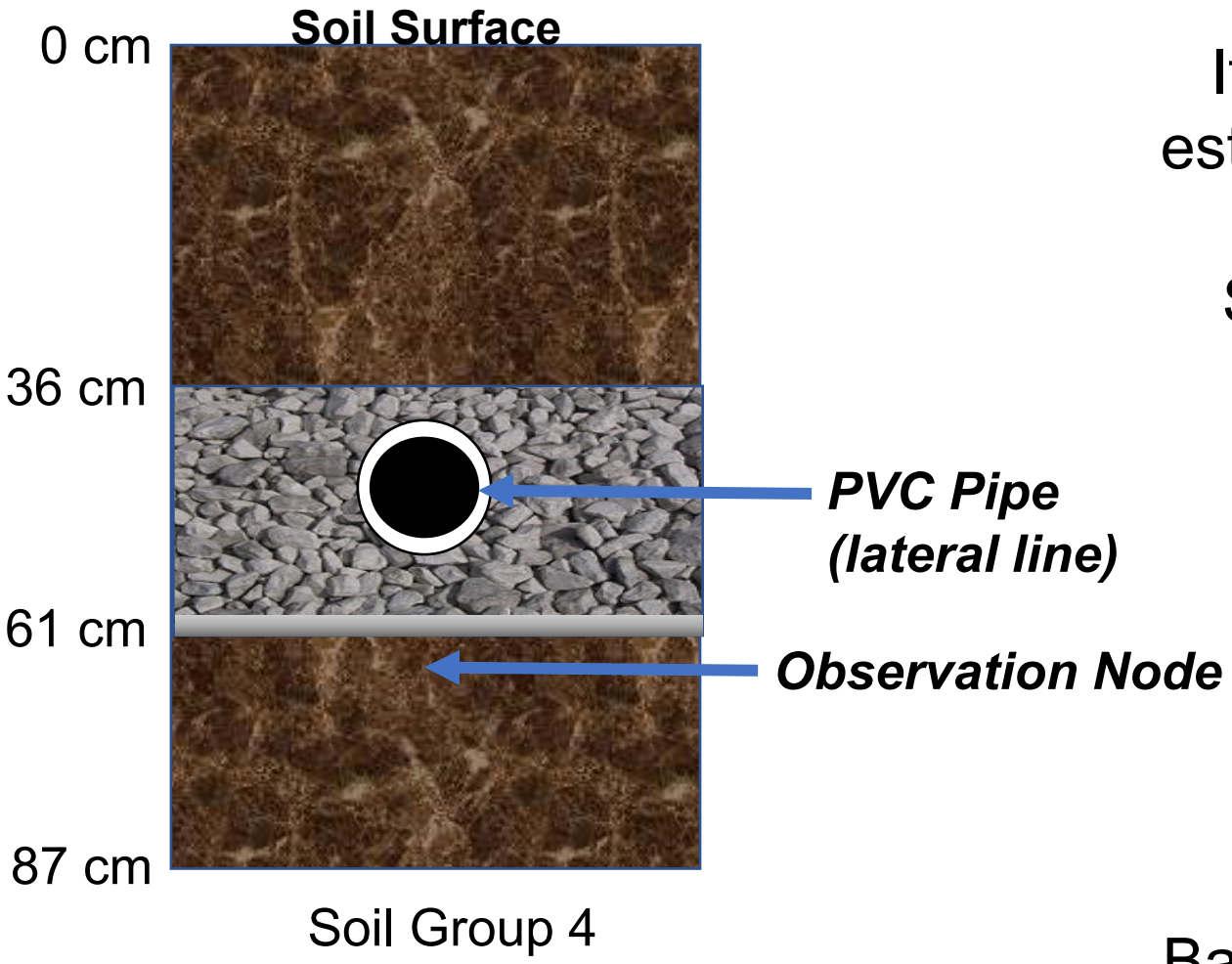
- One dimensional soil profile
- Depths and thicknesses are derived from the current rules and regulations provided by the Oklahoma DEQ.
- Loading Rate – Based on 3 Bedroom house
  - ***Assumed ~266 gal/day***
  - Soil group 2 – 2.58 cm d^{-1}
  - Soil group 3 – 1.20 cm d^{-1}
  - Soil group 4 – 0.62 cm d^{-1}
- Observation node was inserted directly beneath the soil trench.

HYDRUS 1D – Soil Profile



- Profile boundary conditions, biomat, and trench parameters (Radcliffe & Bradshaw, 2014)
- Lower boundary condition – Free Drainage
- Two modeled soil surface conditions: Bare Soil and Constant Live Grass Cover

Definition of Failure/Success of Treatment



If a **negative pressure head** is estimated at the Observation Node

Soil below the gravel layer is unsaturated.

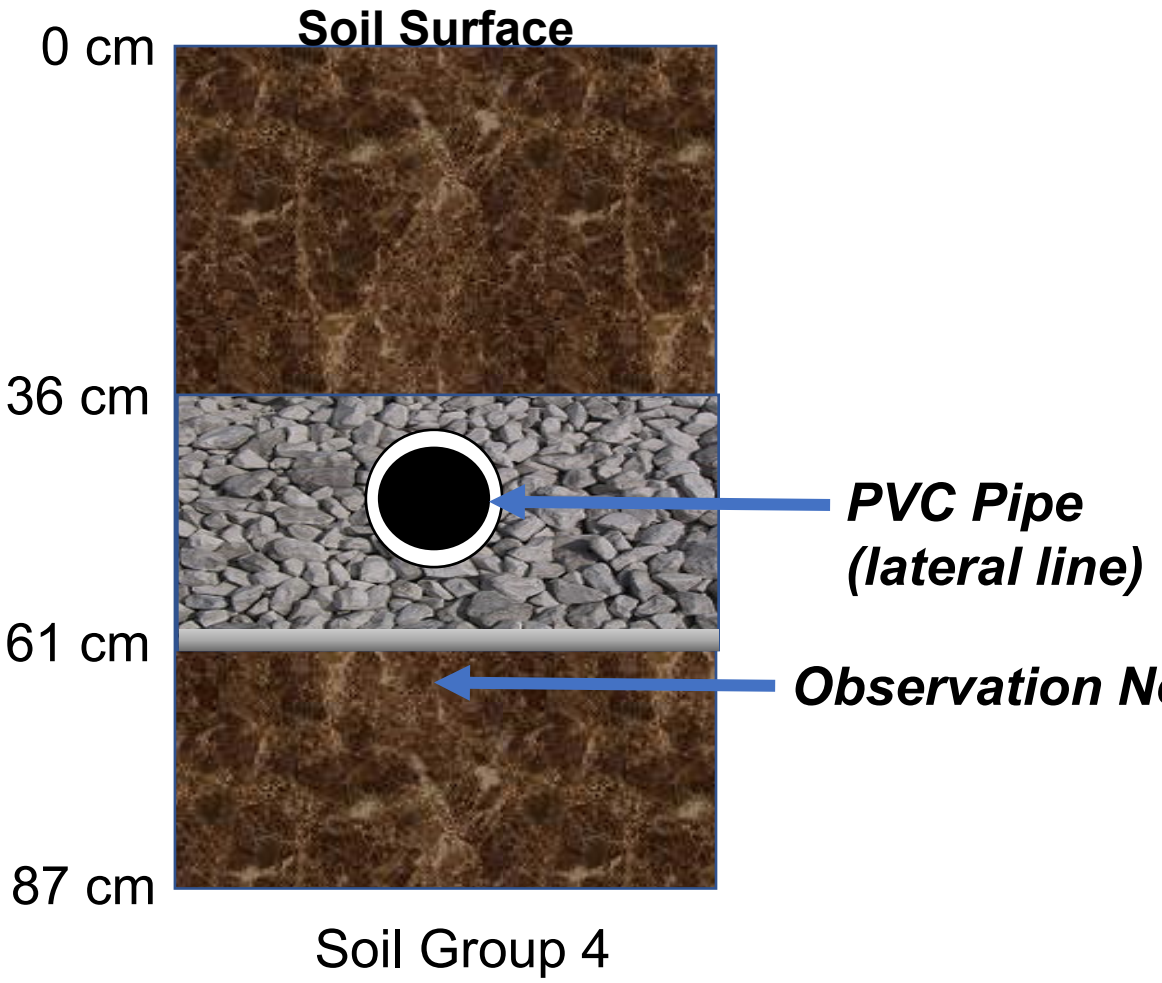
NO hydraulic failure.

It can effectively treat chemical and microbial contaminants.

and

Back-flow and Surfacing is unlikely

Definition of Failure/Success of Treatment



If a **positive pressure head** is estimated at the Observation Node

↓

Soil below the gravel layer is saturated.

↓

Hydraulic FAILURE.

It cannot effectively treat chemical and microbial contaminants.

and

Back-flow and Surfacing is likely

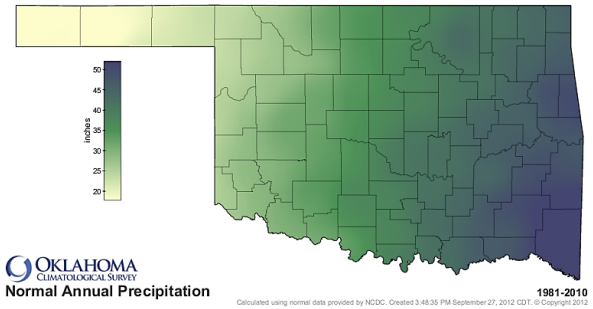
Results

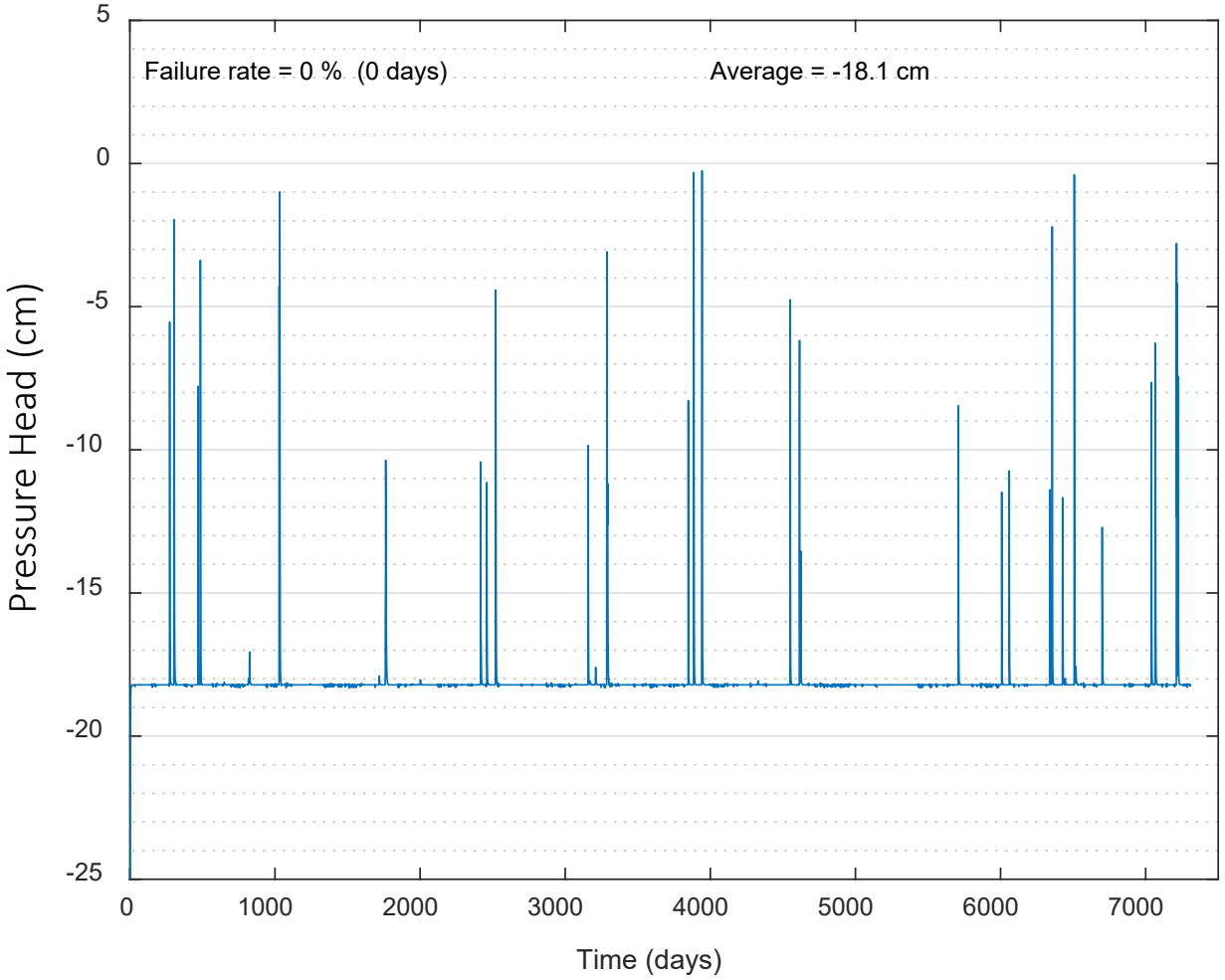
- Simulation results for Soils groups 2 (Loamy Sand) and 3 (Loam) did not yield any failures across all nine climate regions
  - This was also true despite the size reductions (10-40% reductions)
- Focus from hereon will be on Soil Group 4 (Clay Loam)

Results

Panhandle – Soil Group 4
Bare Soil Surface
(Current Sizing Regulation)

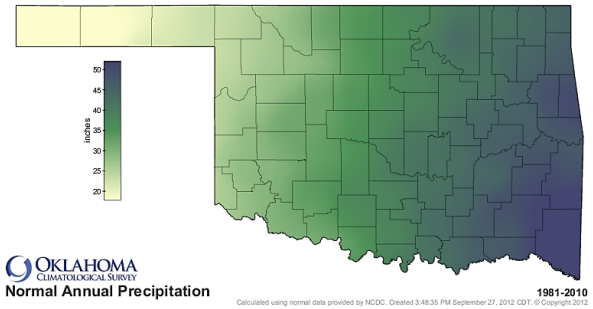
- Average Pressure Potential = -18.1 cm
- Failure rate = 0%
- Total failures = 0 days

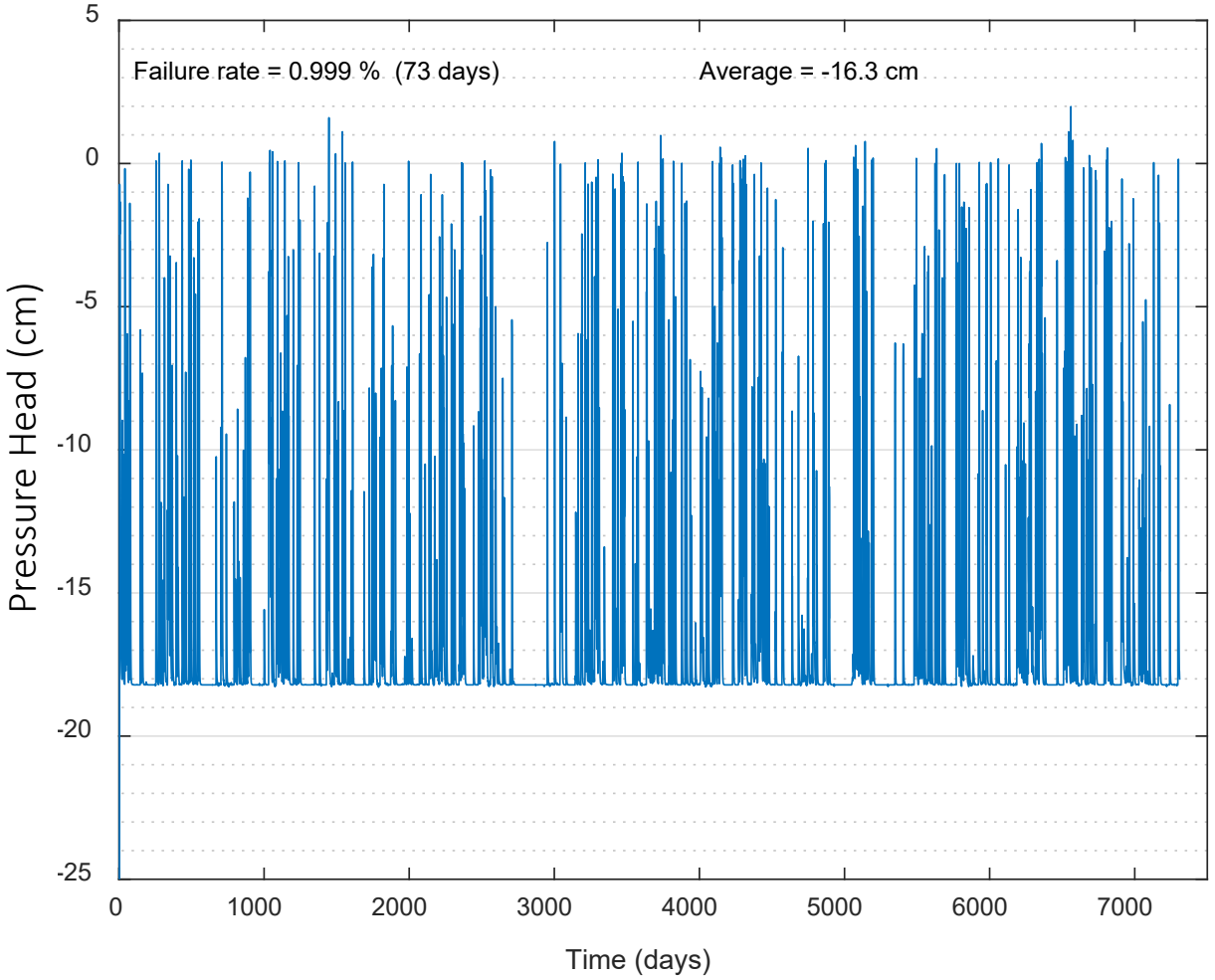




Southeast – Soil Group 4 Bare Soil Surface
(Current Sizing Regulation)

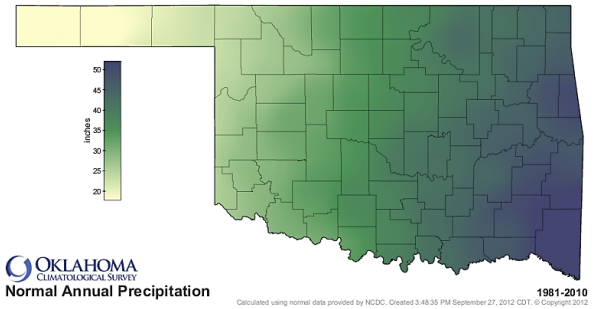
- Average Pressure Potential = -16.3 cm
- Failure rate = 0.999%
- Total failures = 73 days

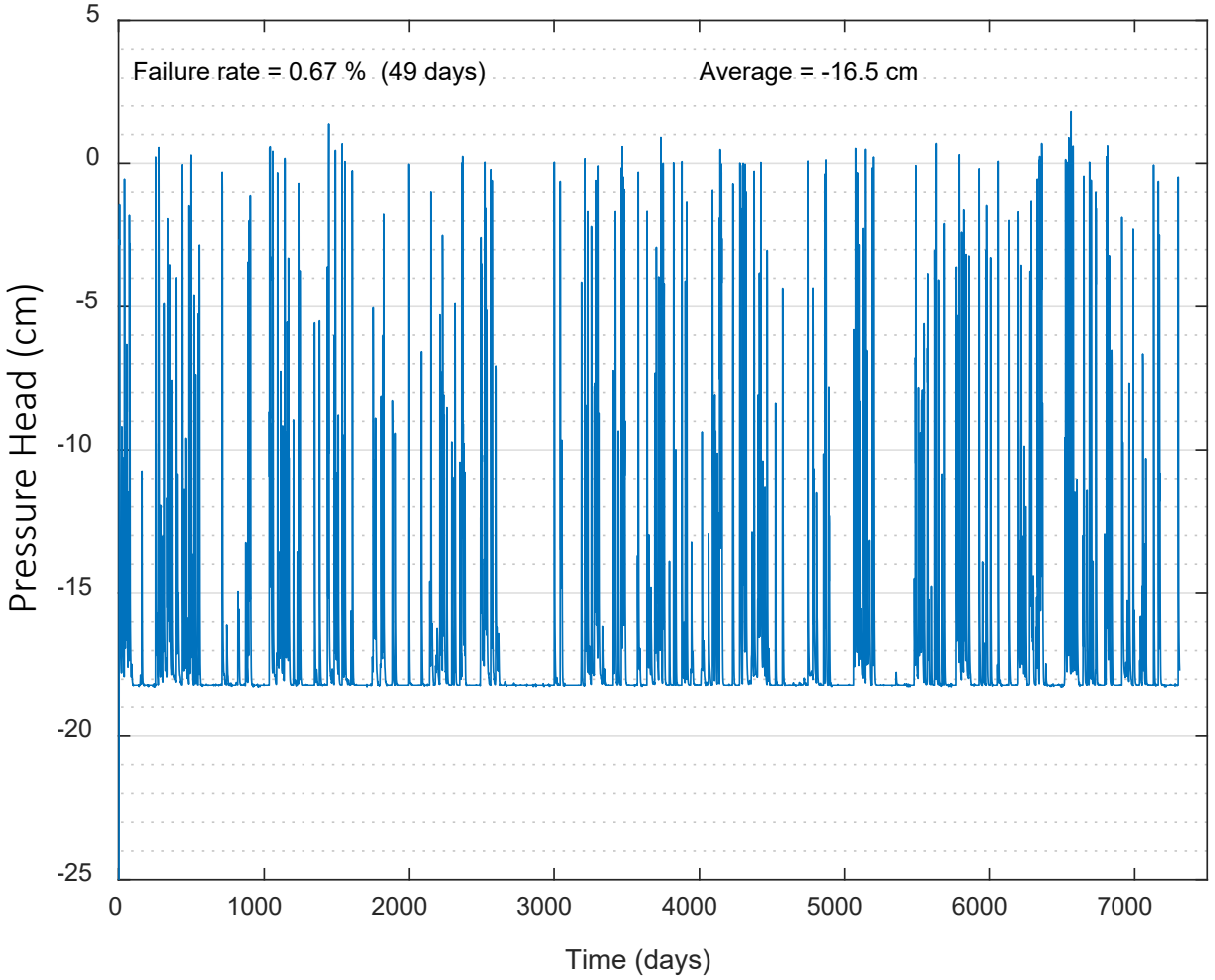




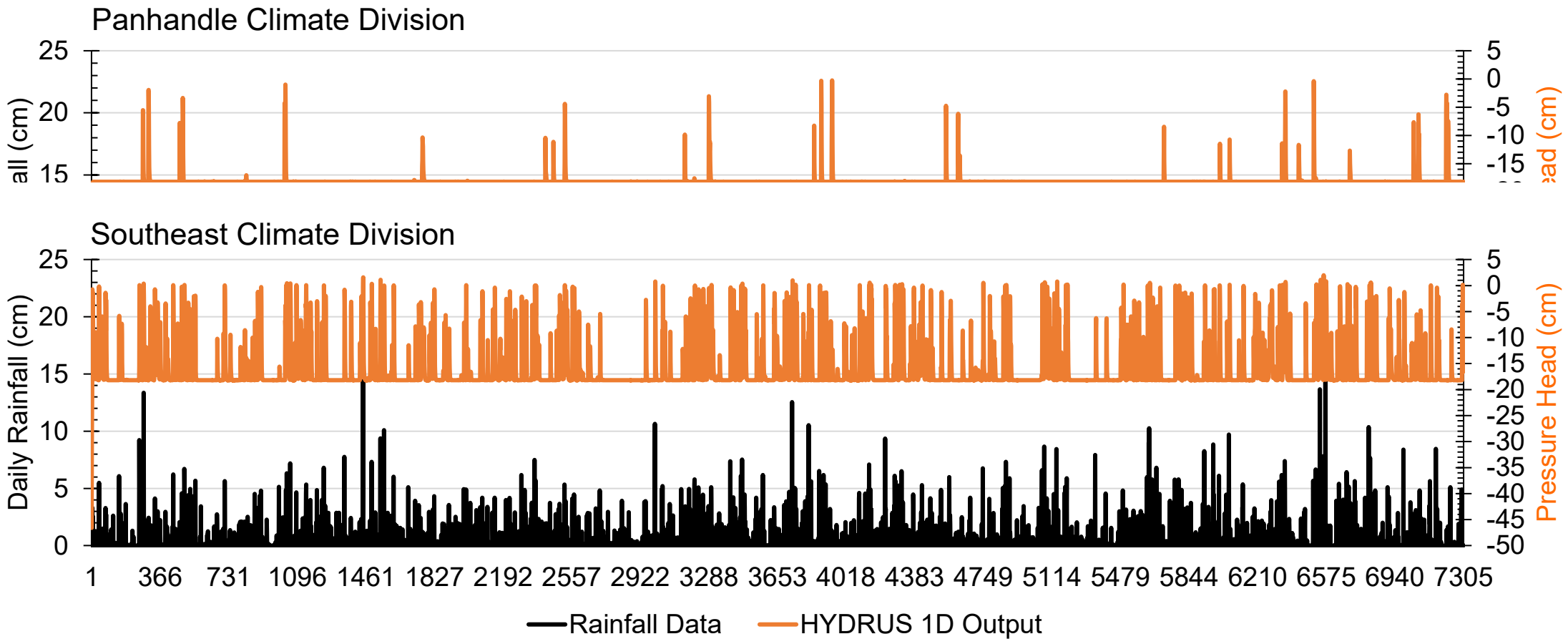
Southeast – Soil Group 4 Constant Live Grass Cover *(Current Sizing Regulation)*

- Average Pressure Potential = -16.5 cm
- Failure rate = 0.67%
- Total failures = 49 days

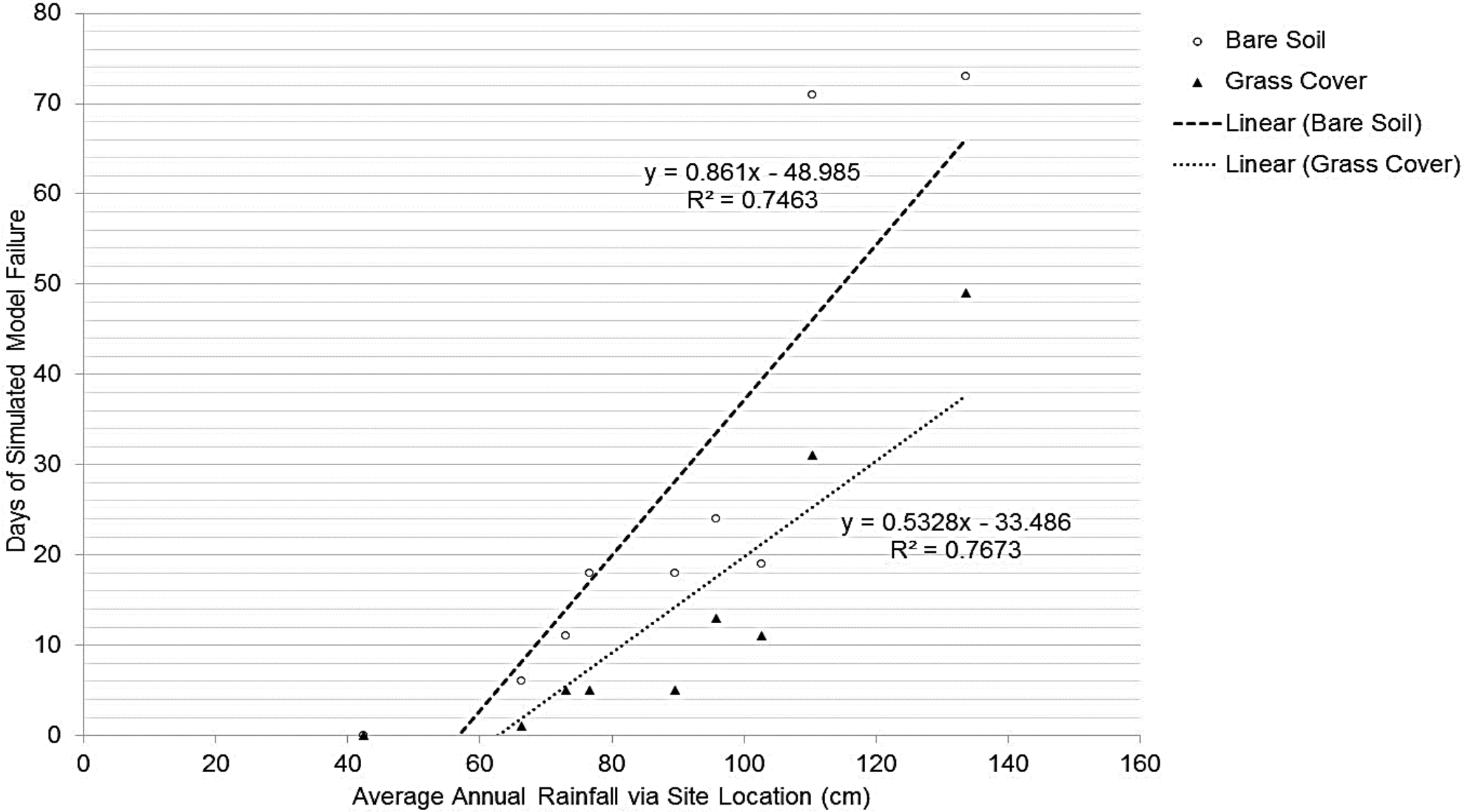




Effect of Rainfall on Pressure Head



Effect of Rainfall on Hydraulic Failure



Failure Rates (out of 7,305 days) for Soil Group 4 Across Climate Divisions under **Bare Soil**

	Panhandle	West Central	Southwest	North Central	Central	South Central	Northeast	East Central	Southeast
Current Regulation	0.00	0.08	0.25	0.15	0.25	0.33	0.26	0.97	0.99
10% Reduction	0.01	0.09	0.23	0.16	0.26	0.37	0.27	0.97	0.99
20% Reduction	0.03	0.10	0.23	0.15	0.29	0.42	0.32	1.04	1.04
30% Reduction	0.01	0.11	0.33	0.18	0.33	0.48	0.33	N/A	1.07
40% Reduction	0.00	0.10	0.36	0.19	0.36	0.52	0.41	N/A	1.18

Failure Rates (out of 7,305 days) for Soil Group 4 Across Climate Divisions under **Grass Cover**

	Panhandle	West Central	Southwest	North Central	Central	South Central	Northeast	East Central	Southeast
Current Regulation	0.00	0.01	0.07	0.07	0.16	0.18	0.15	0.42	0.67
10% Reduction	0.00	0.01	0.11	0.08	0.16	0.18	0.16	0.47	0.70
20% Reduction	0.00	0.01	0.11	0.08	0.19	0.21	0.16	0.51	0.70
30% Reduction	0.00	0.01	0.12	0.07	0.22	0.21	0.19	N/A	0.83
40% Reduction	0.00	0.01	0.12	0.08	0.22	0.29	0.21	N/A	0.92

Limitations

- Modeling simulations of hydraulic performance do not consider treatment effectiveness.
- Modeling scenarios assess the flow of pure water in hydraulic simulations to estimate the flow of wastewater effluent.
- Modeling simulations do not consider the effect of lower boundary conditions on hydraulic performance.
- Modeling simulations only consider one-dimensional vertical hydraulic flow.
- Both soil surface conditions are a simple model that does not accurately represent real-world conditions.
- Soil material in the profiles are assumed to be homogeneous.

Key Findings

- Climate gradient is a factor affecting hydraulic performance of the soil treatment area for conventional on-site wastewater treatment systems.
  - *Precipitation events were triggers for hydraulic failure of the model.*

- Sizing reductions for the soil treatment area of conventional on-site wastewater treatment systems are feasible for some regions and soil types up to at least 40%.
  - Soil groups 2 (loamy sand) and 3 (loam)
  - Soil group 4 (clay loam)

Other Important Findings

- Rainfall could theoretically be used to estimate potential hydraulic failure for conventional septic systems.
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Thank You!

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