Hydraulic and water quality analysis of an established bioretention cell using controlled flood testing

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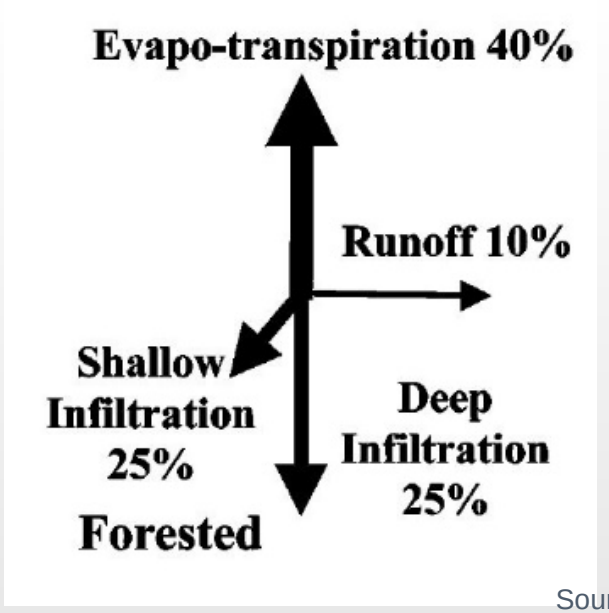
26th Annual Conference

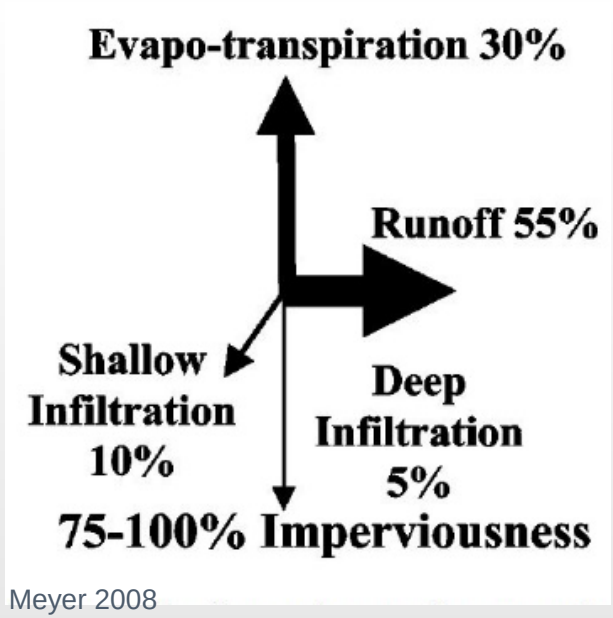
Stillwater, OK

6th April 2017

Introduction

- Urbanization
  - >50% of world population live in urban areas (UN DESA 2014).
  - 2/3^{rds} of Oklahomans live in urban areas
  - National urban area population is increasing 1.2 times the national average
  - Runoff can negatively alter the physical, chemical, and biological components of streams (Paul and Meyer 2008)

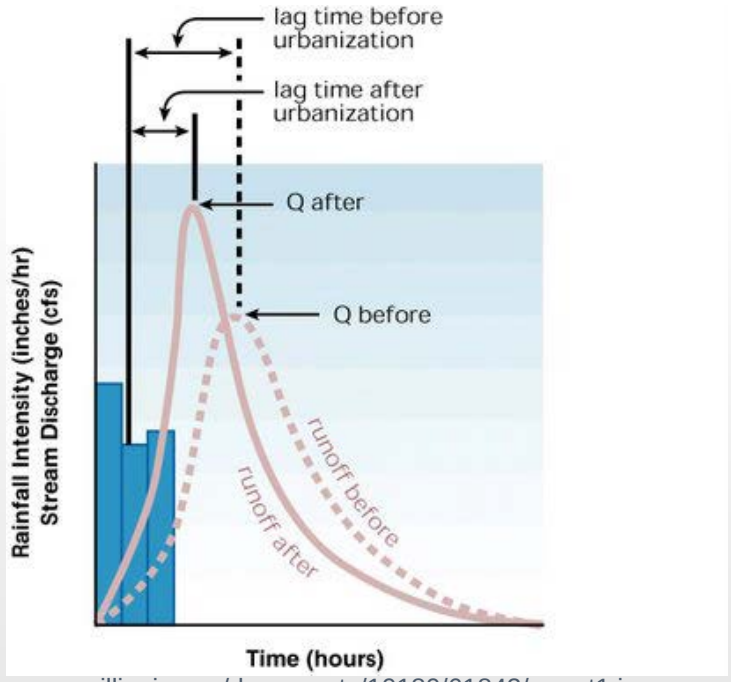




Source: Paul and Meyer 2008

Low Impact Development (LID)

- Maintain or restore the natural hydrology while promoting ecosystem services and sustainability
- Longevity: LID methods have been shown to positively impact water quantity and quality, though long-term results are variable and limited both temporally and geographically.



cmap.illinois.gov/documents/10180/61842/mgmt1.jpg

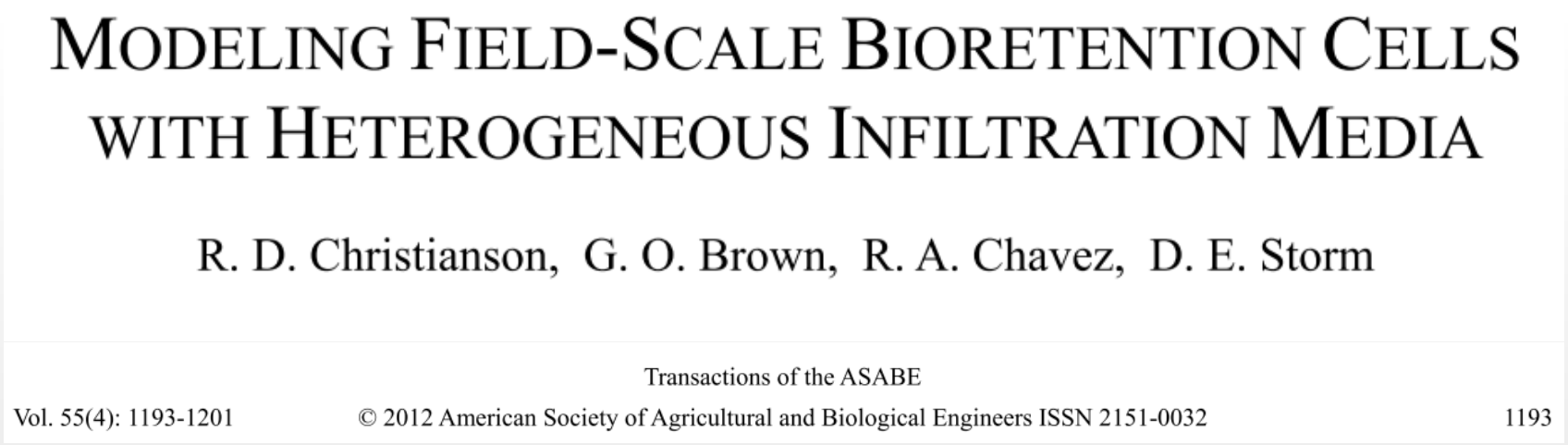
Bioretention Cell (BRC)

Background

- Validating BRC hydraulics with time
  - Hydraulics have been quantified with ring infiltrometer methods or stormwater monitoring (Emerson and Traver 2008; Jenkins et al. 2010).
  - Flooding method employed by Nichols and Lucke (2016) was successful on 10-year old small bioretention cells. Leaching occurred, but data from this level of testing is limited.

Background

- Grove, OK flood testing by Christianson et al. (2012)
  - Completed to validate a bioretention cell model
  - 43% (dry) and 47% (wet) retention efficiencies
  - 3.4 in/hr steady-state infiltration rate in the bioretention cell



MODELING FIELD-SCALE BIORETENTION CELLS WITH HETEROGENEOUS INFILTRATION MEDIA

R. D. Christianson, G. O. Brown, R. A. Chavez, D. E. Storm

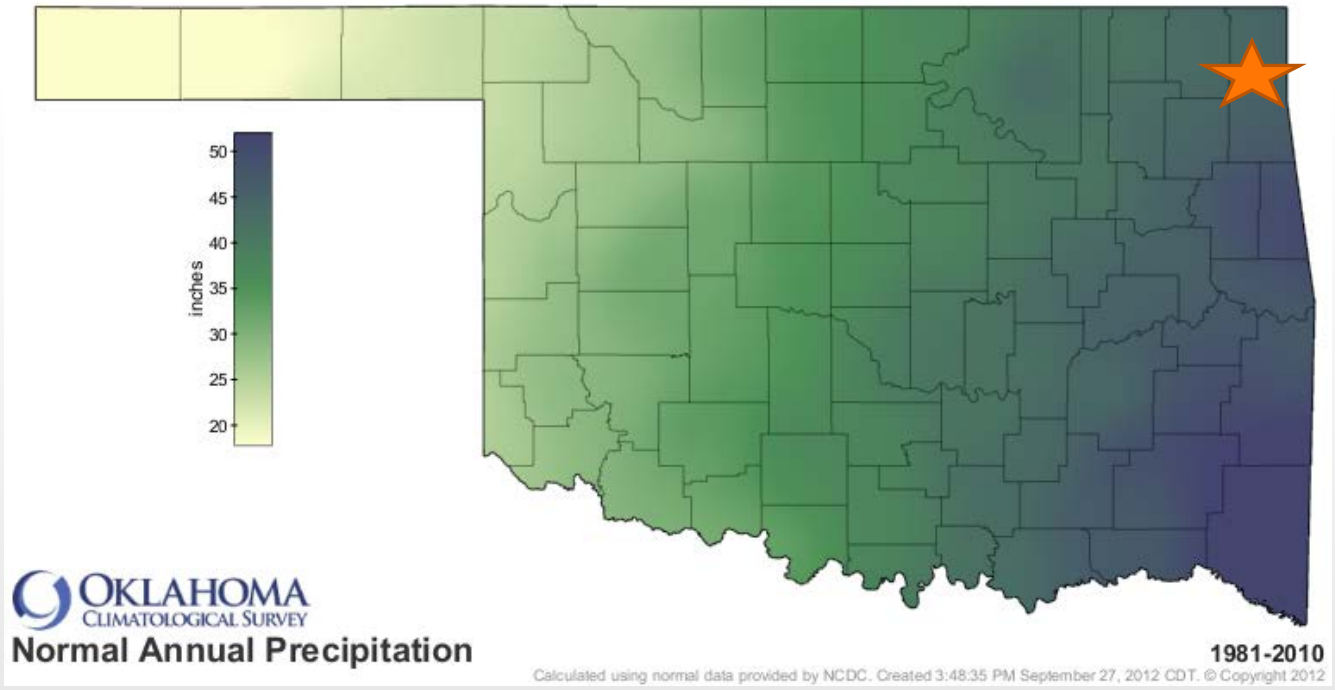
Transactions of the ASABE
Vol. 55(4): 1193-1201 ISSN 2151-0032

Objective

1. Evaluate hydraulics of an aged bioretention cell under low and high antecedent moisture conditions
2. Quantify water quality parameters during testing
3. Compare results to previous study and design specifications

Site description

- Grove, OK
- Precipitation statistics
  - 1.1 inches – 90th percentile precipitation depth
  - 0.89 inches – runoff produced by the 90th storm event using the CN method



Methods

- Study site description (Chavez et al. 2015)
  - 5% fly ash in media
  - 25% of the surface is sand plugs
  - Sizing: storage for 1 inch of runoff.
    - 0.5 inches in the media
    - 0.5 inches ponded on the surface

Site	Cell Area (m^2)	Contributing Area (m^2)	Catchment Type
Grove High School	149	2600	Asphalt

Methods

- Flooding test method
  - Similar to Christianson et al. (2012)
  - Dry and wet tests antecedent moisture conditions
  - Constant flow rate at the inlet from a fire hydrant
  - Flow rate measurements with ISCO 720 submerged flow pressure module

Inlet

1-ft H-flume

Overflow

2.5-ft sharp weir

Underdrain

3-inch Palmer-Bowlus

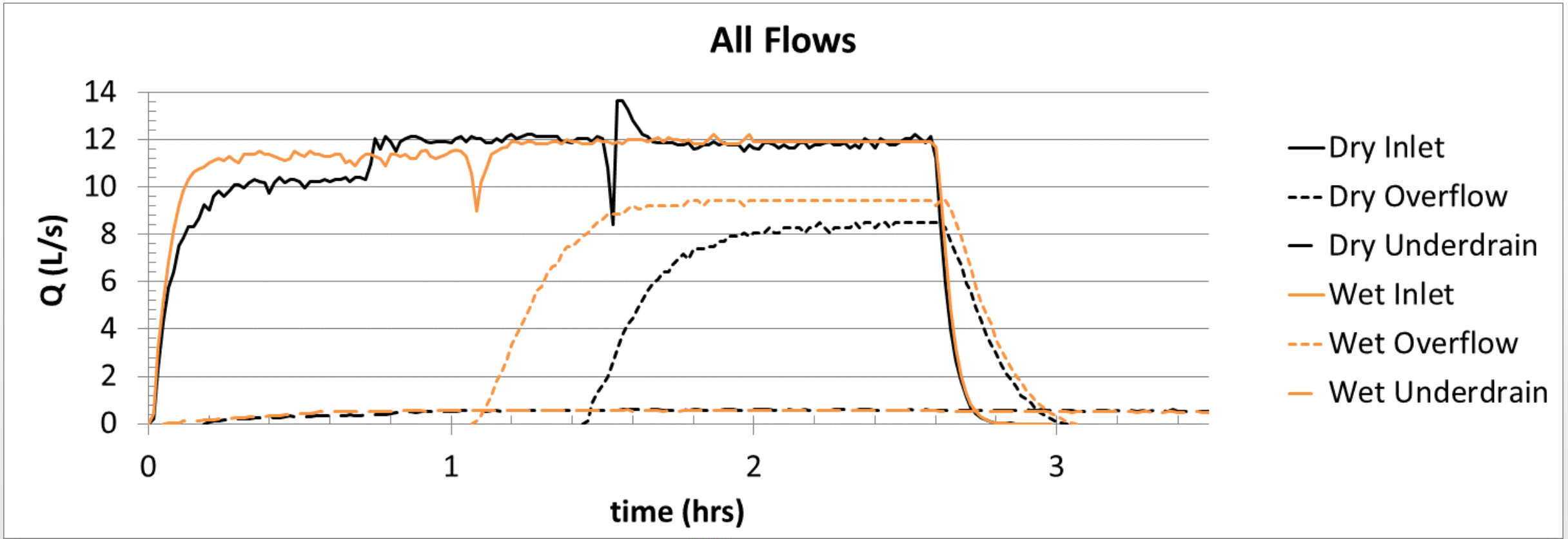
Methods

- Water sampling
  - Collect time-based samples at the inlet and underdrain with an ISCO 6712 refrigerated sampler
  - Collect time-base samples at the overflow by hand
  - Analyze in the laboratory for
    - EC, Cl, NO3-N, Ortho P, pH – SWFAL
    - Turbidity – Hach 2100Q benchtop turbidity meter
    - Total coliform, *E. coli*, and Enterococci with IDEXX Quanti-Tray/2000

- Statistical methods
  - Check normality
  - ANOVA with Tukey comparison of concentration and mass

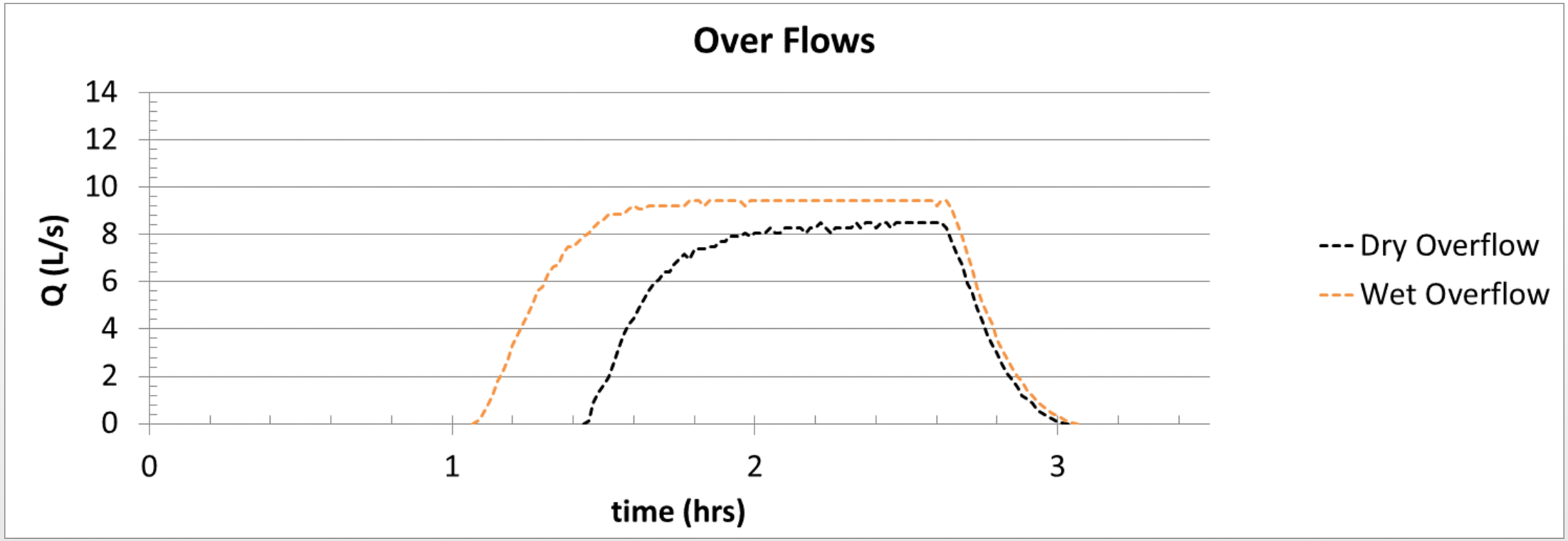
Hydrographs

	In (L/s)	Over (L/s)	Underdrain (L/s)	% Total reduction	% Underdrain reduction
Dry test	11.8	8.3	0.57	25	95
Wet test	11.6	9.4	0.55	16	95



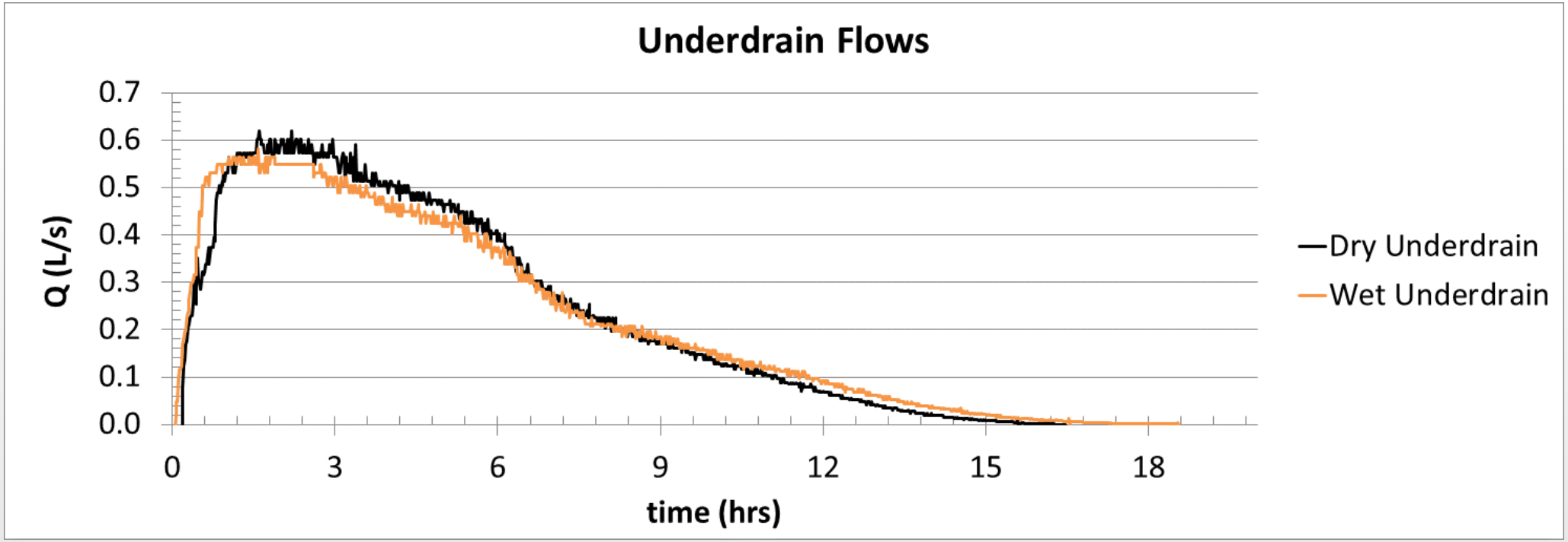
Overflow timing

	Time to start (min)	Time to steady-state (min)
Dry test	86	2.1
Wet test	64	1.8
Difference	*22*	*0.3*



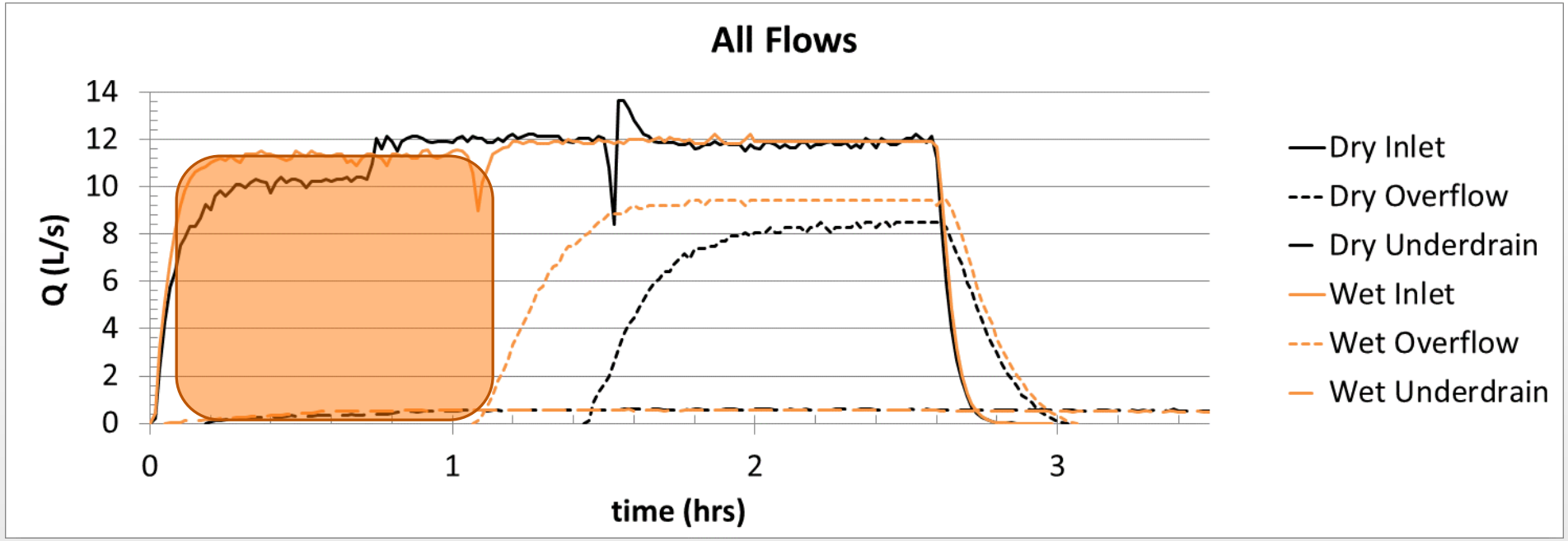
Underdrain flow timing

	Time to start (min)	Time to steady-state (hr)	Duration (hr)
Dry test	12	3.0	16.8
Wet test	4	2.1	18.6
Difference	*8*	*0.9*	*2.8*



Equivalent rainfall depths

	Runoff depth before overflow started (in)	Equivalent rainfall depth before overflow started (assume CN = 98) (in)	Grove, OK 90th percentile storm (in)
Dry test	0.84	1.05	1.11
Wet test	0.63	0.83	

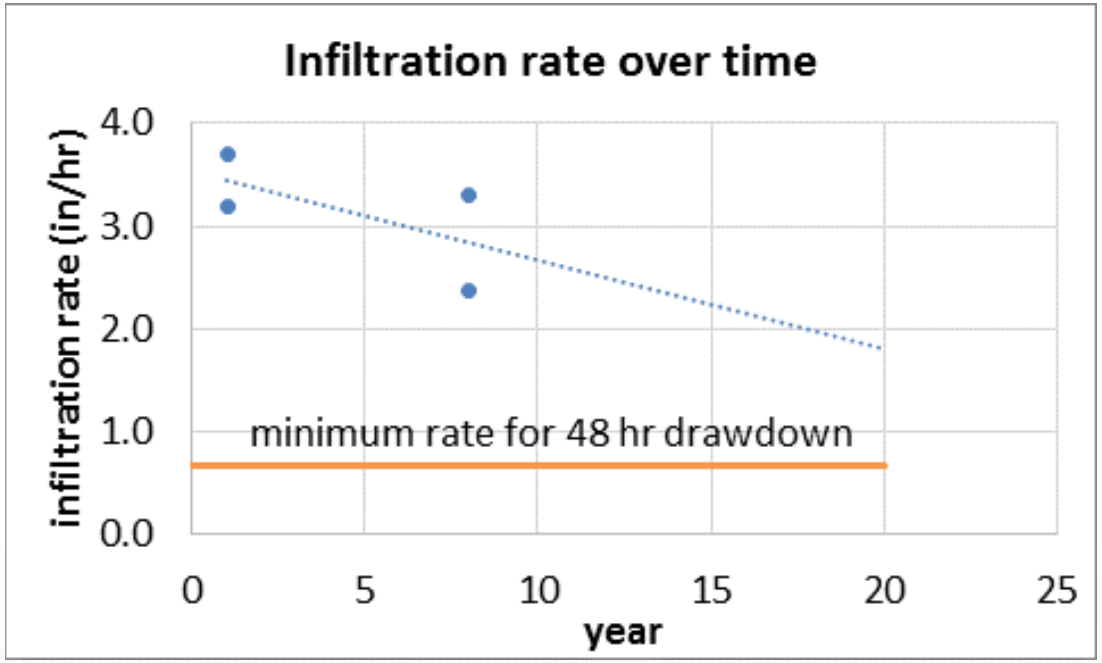


Equivalent rainfall depths

	In Rainfall (in)	Out Rainfall (in)	% Reduction	Curve number	Hydrologic soil group	Land type
8-yr Dry	1.61	0.75	54	90	D	Open space (poor condition)
8-yr Wet	1.64	0.99	39	93	D	Urban mix
1-yr dry	3.29	1.80	45	84	D	Open space (fair condition)
1-yr Wet	1.63	0.86	48	91	D	Open space (poor condition)

Media infiltration rates

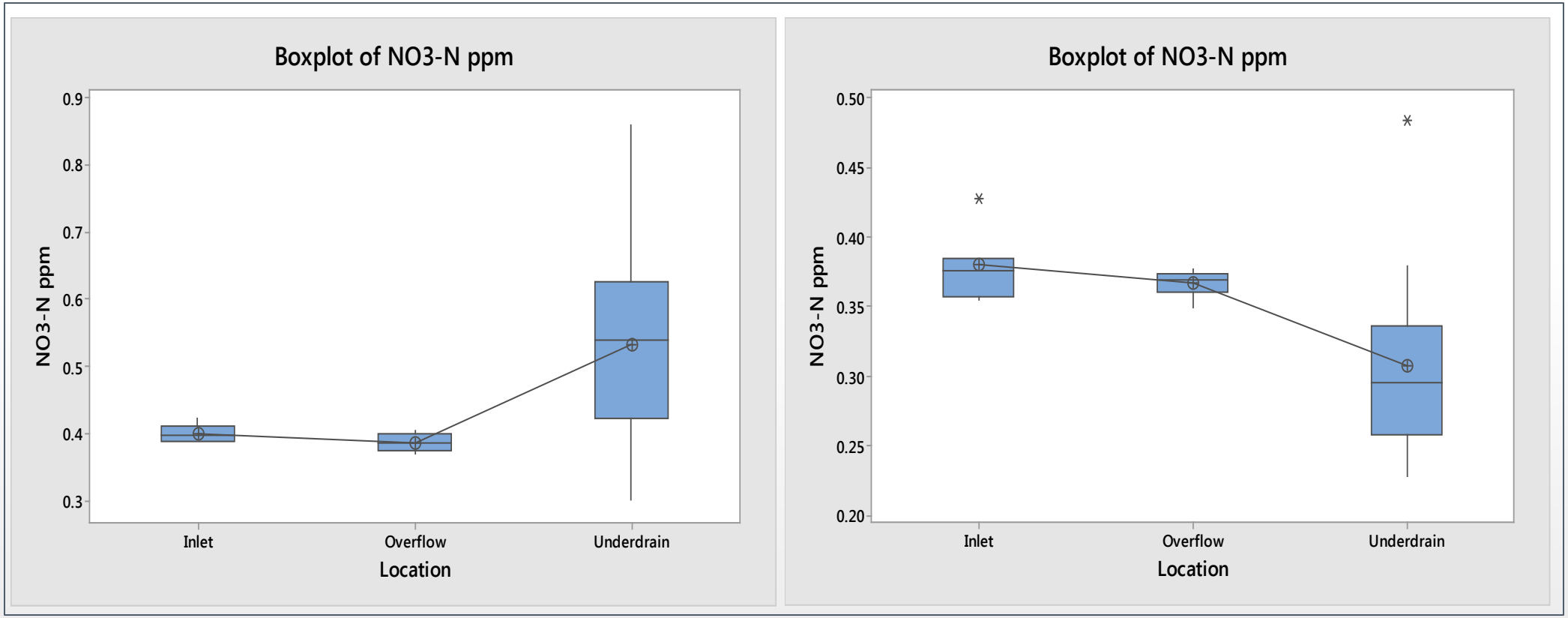
	Infiltration (in/hr)	Average (in/hr)
8-yr Dry	3.3	2.8
8-yr Wet	2.4	
1-yr dry	3.2	3.4
1-yr Wet	3.7	



- Loamy sand or sandy loam soil infiltration rates

Nitrate

- Only water quality parameter with significant changes for both the dry and wet tests



Conclusions

- Better hydraulic performance during the dry season
  - 95% steady-state flow rate reduction between inlet and underdrain
- Potentially better water quality during the wet season
  - Reduced nitrate concentration during wet test
- The 8-year old cell continuous to capture approximately the first 1 inch of runoff
- Media infiltration rate around 3 in/hr

Thank you

- We thank Grove Public Schools and the City of Grove, OK. Additionally, we thank Brad Rogers and Jason Walker for help with the flood experiments, and Saroj Kandel for assistance setting up and maintaining equipment prior to this study.