



reliable rainwater is just a roof away!

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acknowledgments

- Meadows Foundation Endowment to support Graduate Fellows and Research Assistants
- Meadows Foundation Endowment for the Water Policy Program
- National Oceanic and Atmospheric Administration

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outline

- what is rainwater harvesting?
- is rainwater reliable?
- calculating firm yield
- reliable rainwater!
- next steps
- conclusions

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What is your current relationship status with rainwater harvesting?

- A. rainwater curious
- B. collect with barrels
- C. collect with a big-ole tank(s) [<5,000 gallons]
- D. collect with a big-ole tank(s) [>=5,000 to 20,000 gallons]
- E. collect with a big-ole tank(s) [>20,000 gallons]
- F. someone told me this presentation would be about cats

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If you collect rainwater, what do you use it for?

- A. potable purposes (drinking)
- B. non-potable purposes-outdoors
- C. non-potable purposes-indoors
- D. I don't collect rainwater
- E. why aren't you talking about cats?

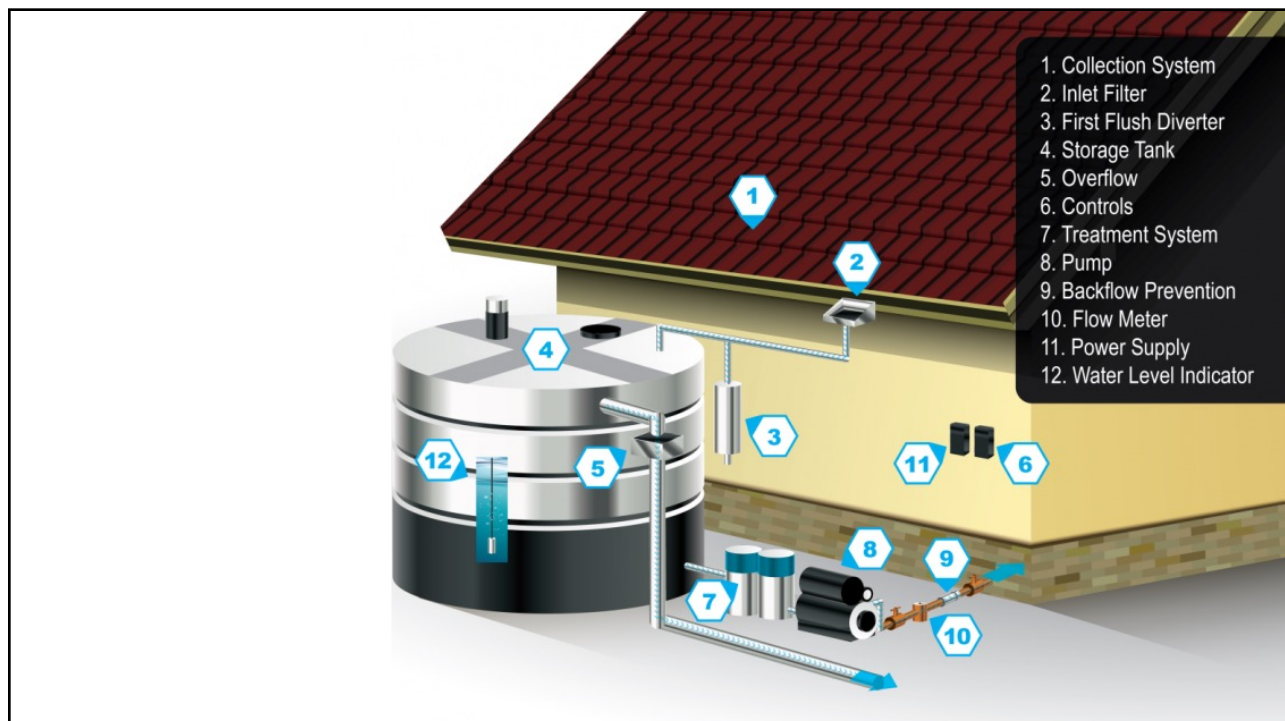
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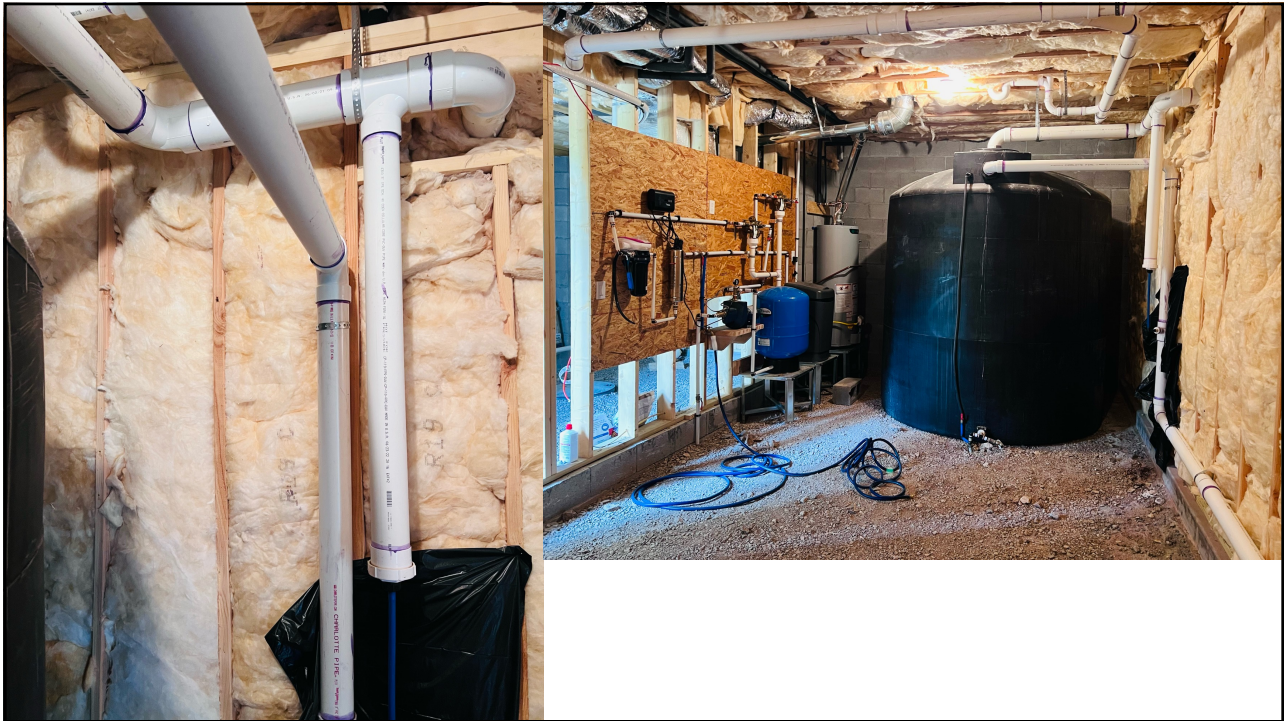
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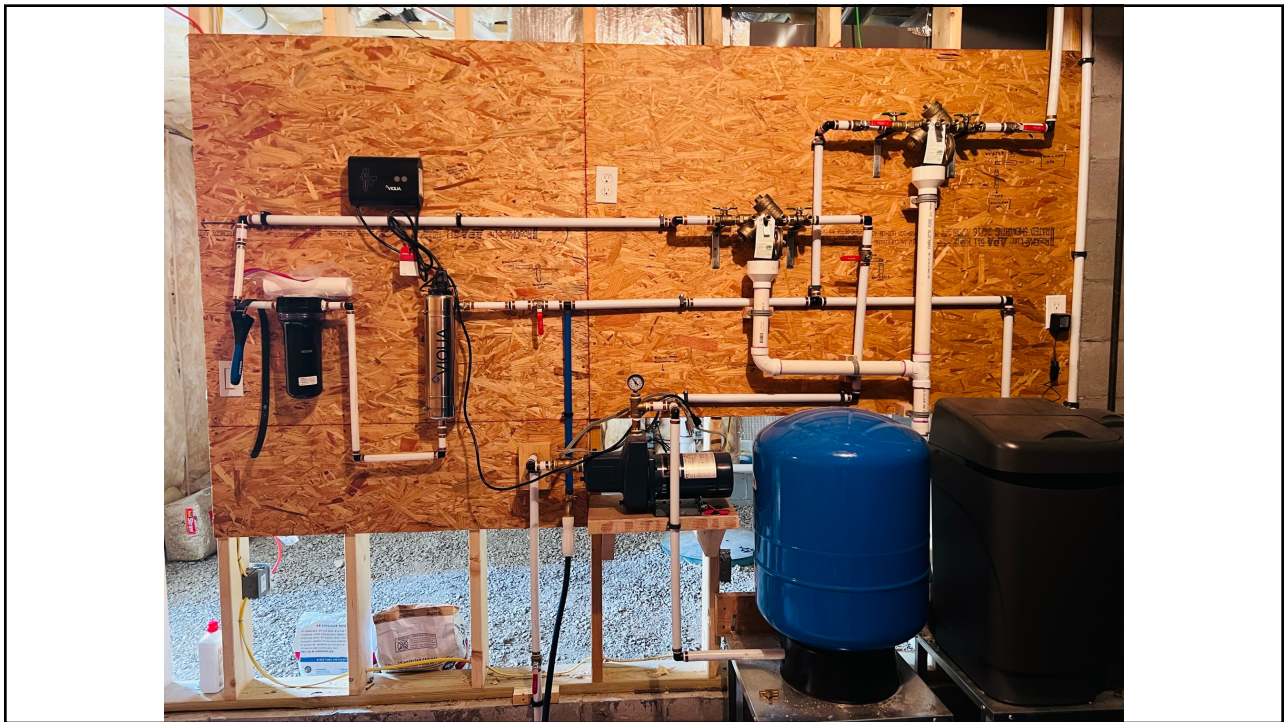
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why rainwater?

- may be the only option
- reduce the use of source supplies
- better quality
- may be cheaper than drilling a well
- plants like it better
- self/back-up supply
- can help build climate resilience
- may be required
- it's fun!

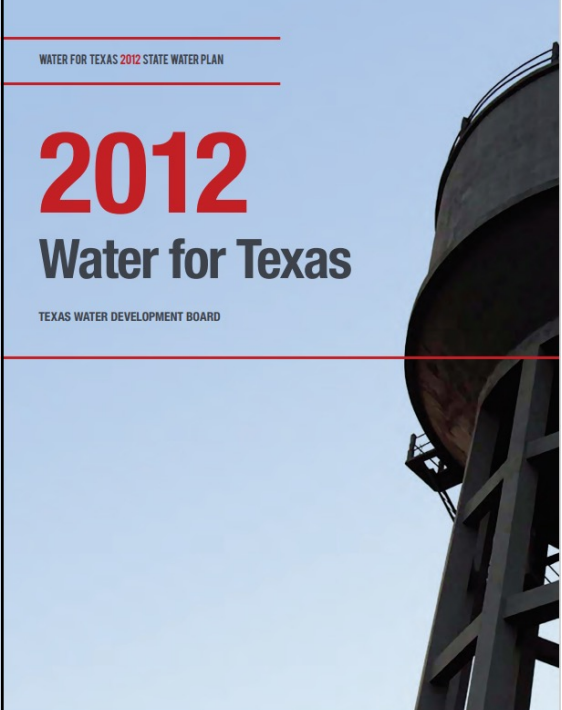
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WATER FOR TEXAS 2012 STATE WATER PLAN

2012

Water for Texas

TEXAS WATER DEVELOPMENT BOARD

“While it is often a component of municipal water conservation programs, **rainwater harvesting was not recommended as a water management strategy to meet needs since, like brush control, the volume of water **may not be available during drought conditions.**”**

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Firm Yield

- 2022 State Water Plan definition:
 - “Maximum water volume a reservoir can provide each year under a repeat of the drought of record using anticipated sedimentation rates and assuming that all senior water rights will be totally utilized and all applicable permit conditions met.”
- Generalized definition:
 - **Maximum volume of water a source can provide each year under a repeat of the drought of record**

2022
State Water Plan

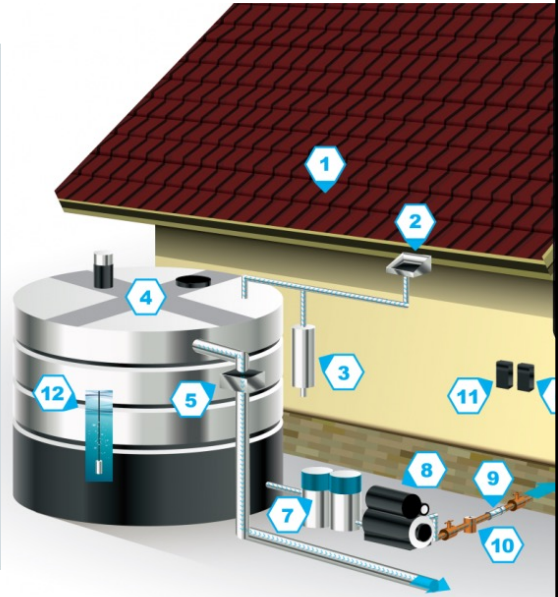
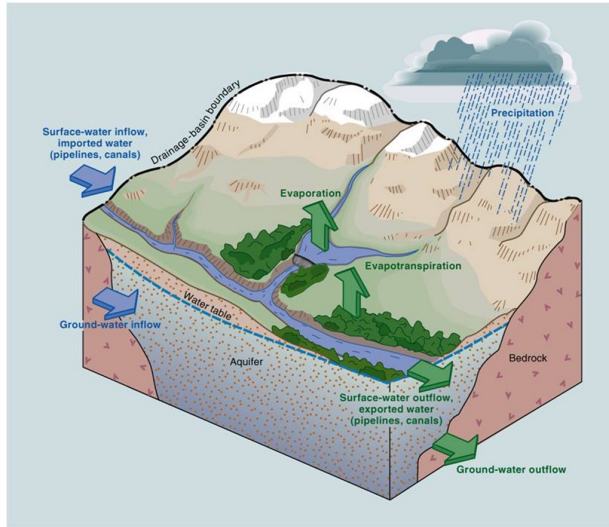
WATER FOR TEXAS

Texas Water
Development Board



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analogous (but different [but the same])



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Rainwater Harvesting as a
Development-Wide Water Supply Strategy

Final Report
Submitted to The Texas Water Development Board (TWDB)

(TWDB Contract No. 1148321311)

Submitted to the Texas Water Development Board
October 25, 2013

By David Venhuizen, P.E.
Venhuizen Water Works

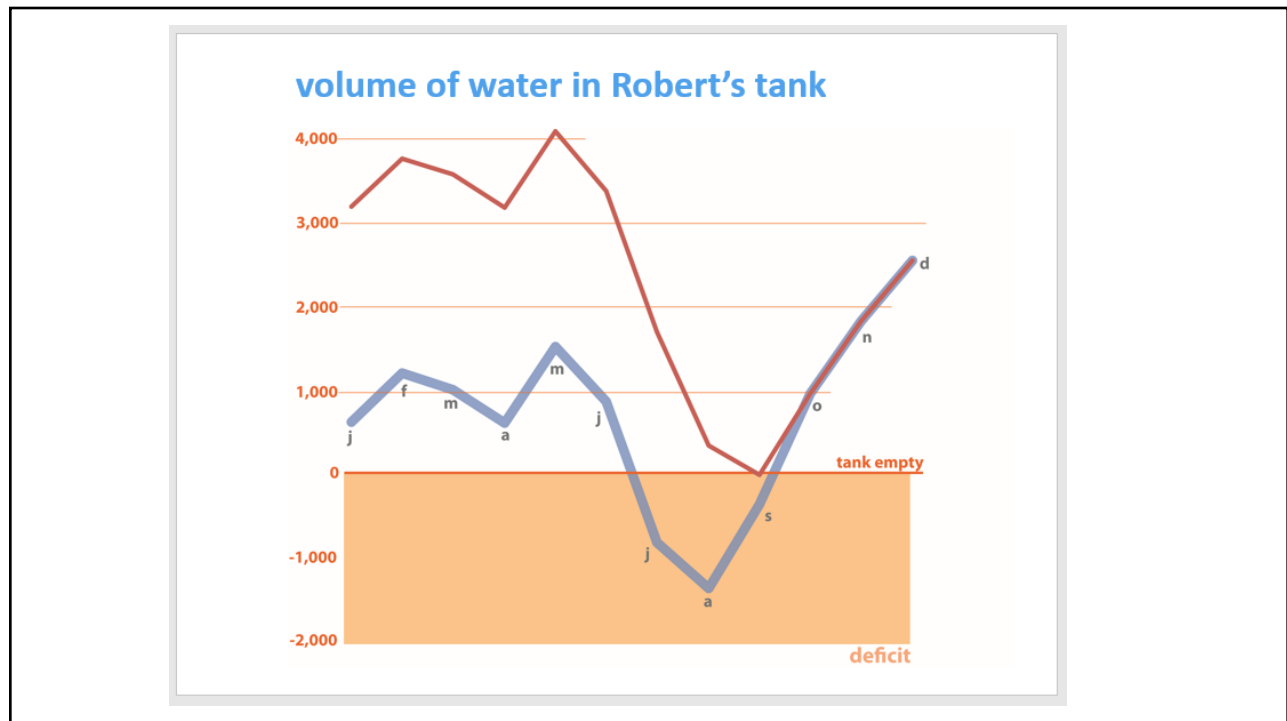
Karen Ford,
White Hat Creative

&

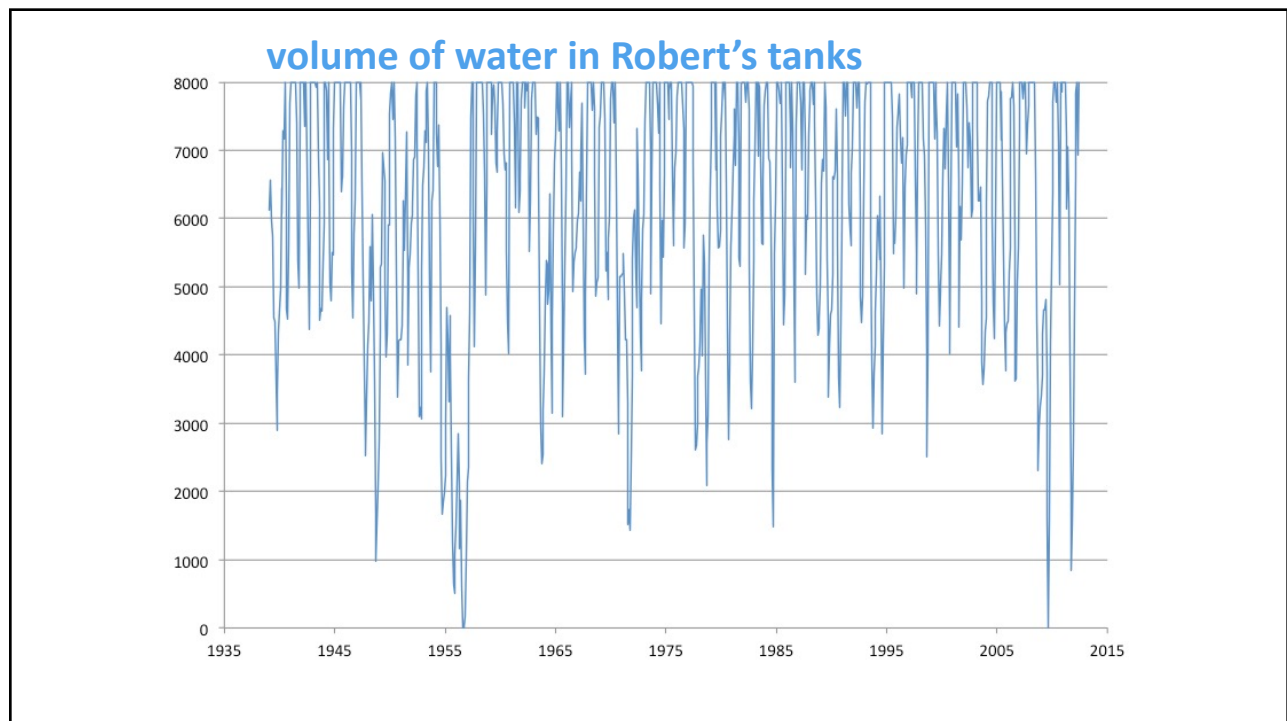
Meredith Miller, Stacy Bray, Shaun Payne and Andrew Sansom
The Meadows Center for Water and the Environment,
Texas State University – San Marcos
(formerly River Systems Institute)

If back-up is
required, then the
firm yield = 0

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why firm yield?

- “100%” reliable
- avoid tank anxiety
- the cost of a firm system may minimize overall “cost”
- increase site, local, and regional resilience

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governing equation

$$V_t = V_{t-1} + R * A * C - V_{ff} - V_u$$

unless
 $V_{ff} > R * A * C$ in which case $V_{ff} = R * A * C$ (2) not enough rain
 $V_t > V_{tot}$ in which case $V_t = V_{tot}$ (3) tank full
 $V_t < 0$ in which case $V_t = 0$ (4) tank empty

volume of tank today
 volume of tank yesterday
 precipitation
 catchment area
 runoff coefficient
 volume first flush
 volume of use

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RAINFAL

(Rainwater Assessment and Interactive eNumerator for Firm-yield Analysis Limits)

RAINFAL (Rainwater Assessment and Interactive eNumerator for Firm-yield Analysis Limits)

Items in red are user-assigned; items in black are calculated

			date	precipitation	
				inches	
Austin			6/1/38	0	
Weather station: Camp Mabry			6/2/38	0	
			6/3/38	0	
user-adjusted parameters:			6/4/38	0.4	
Ar	3,000	ft ²	6/5/38	0.02	
Vt	10,590	gallons	6/6/38	0	
daily demand	70	gallons per day	6/7/38	0	
runoff coefficient	0.92	unitless	6/8/38	0	
			6/9/38	1.6	
conversions & calculations:			6/10/38	0.01	
			6/11/38	0	
Vt	1415.7	ft ³	6/12/38	0	
Vff	4.01	ft ³	6/13/38	0	
daily demand	9.36	ft ³ /ft per day	6/14/38	0	
starting tank storage	50	percent full	6/15/38	0.01	
starting tank storage	128564.0	ft ³	6/16/38	0.07	
dead pool	5	percent full	6/17/38	0	
			6/18/38	0.65	
			6/19/38	0	
Ar	3,010	copy and paste this into the Ar space to auto-calculate firm storage	6/20/38	0	
	3,000		6/21/38	0	
Vt	10,590	copy and paste this into the Vt space to auto-calculate firm storage	6/22/38	0	
	10,590		6/23/38	0	
daily demand	16,571	copy and paste this into the Ar space to auto-calculate firm demand	6/24/38	0	
	70		6/25/38	0	
			6/26/38	0	
			6/27/38	0	
			6/28/38	0.25	

dead pool storage: 530 gallons

lowest storage: 516 gallons

reliability: 100.00 percent

days with no water: 0 days

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system assumptions



- first flush: 50 gallons (...)
- runoff coefficient: 0.92
- starting storage: 60% (but tested for independence from initial conditions)
- 5% **dead pool**
- no evaporative losses
- snow? what's snow?

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analysis assumptions

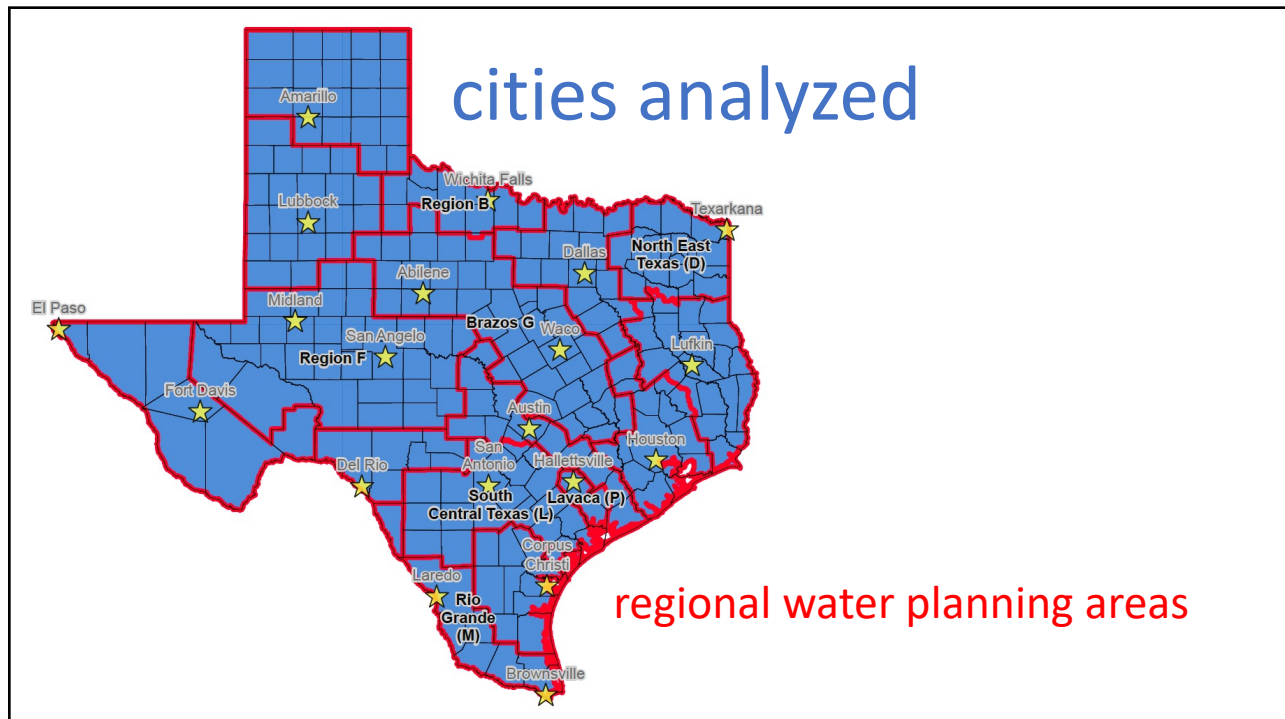
- typical new home catchment = 3,181 square feet
 - assumes a full catch
- typical occupancy of a home in Texas = 2.76 people
- range of use from 10 gallons per person per day to 60
 - range assumes no outdoor use
 - in reality, firm yield is independent of use
 - assumes consistent daily use
- a “reasonable” system has 30,000 gallons of storage
- does not consider economics
- used available daily precip information

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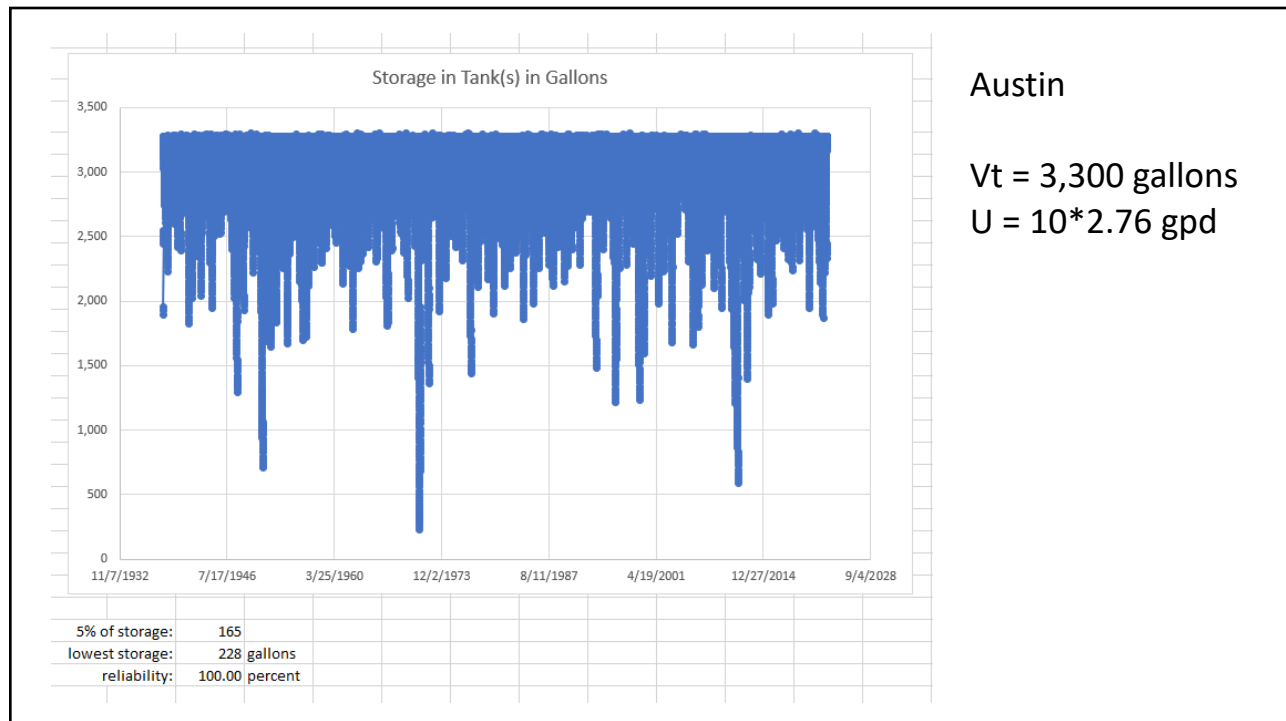
how low can you go?

- rainwater users are efficient (Capehart and Eden, 2021)
- buddy near Bastrop: 10 gpcd
- high-efficiency homes use ~36.7 gpcd (DeOreo and others 2011)
- California recommends indoor water use standards of 55 gpcd by 2023, 47 by 2025, and 42 by 2030 (CA-DWR, 2021)
- Californians use 48 gpcd with a quarter of homes using less than 42 (CA-DWR, 2021)
- Denver Water has goal of 40 gpcd indoors (currently at 50)

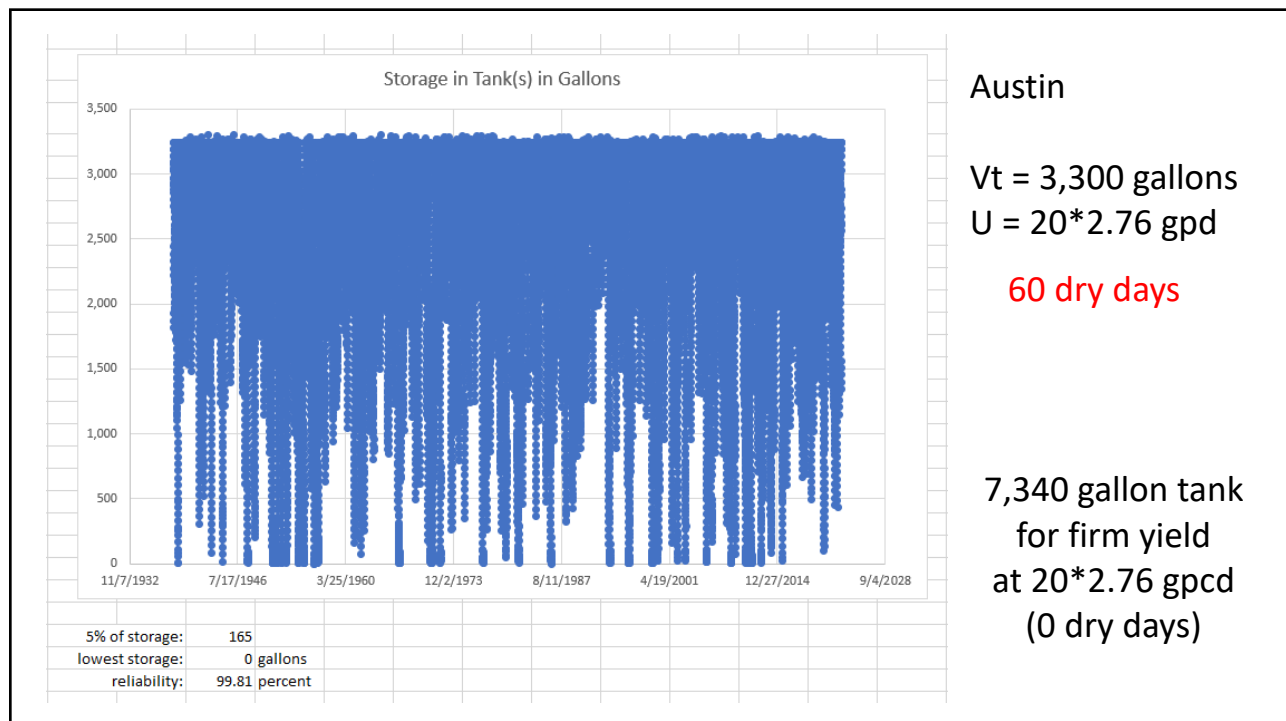
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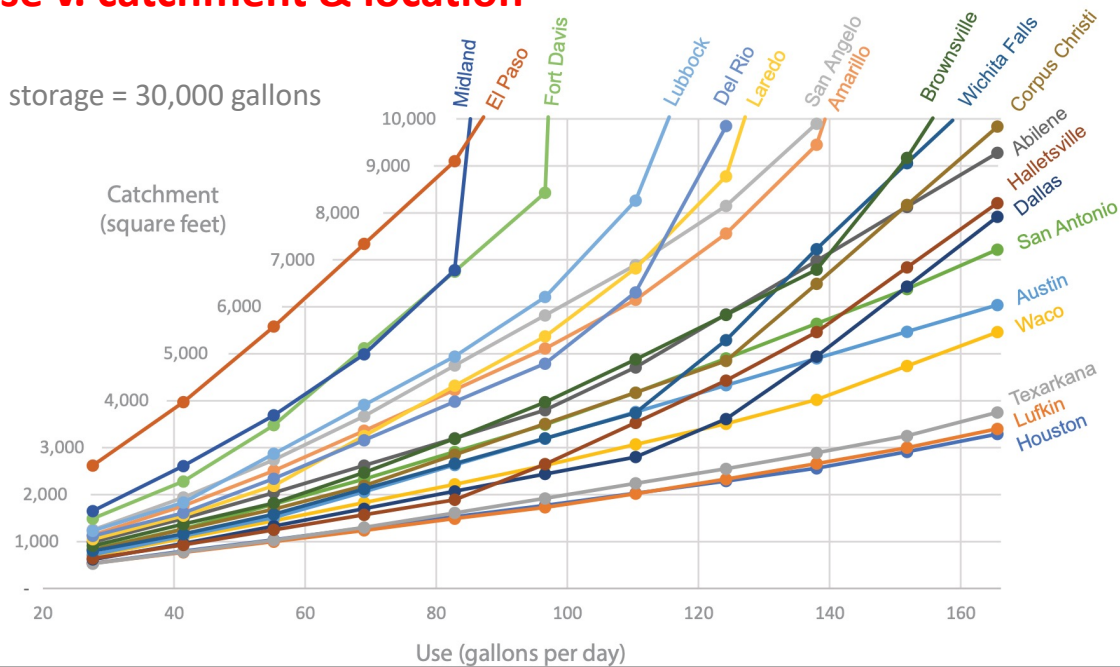


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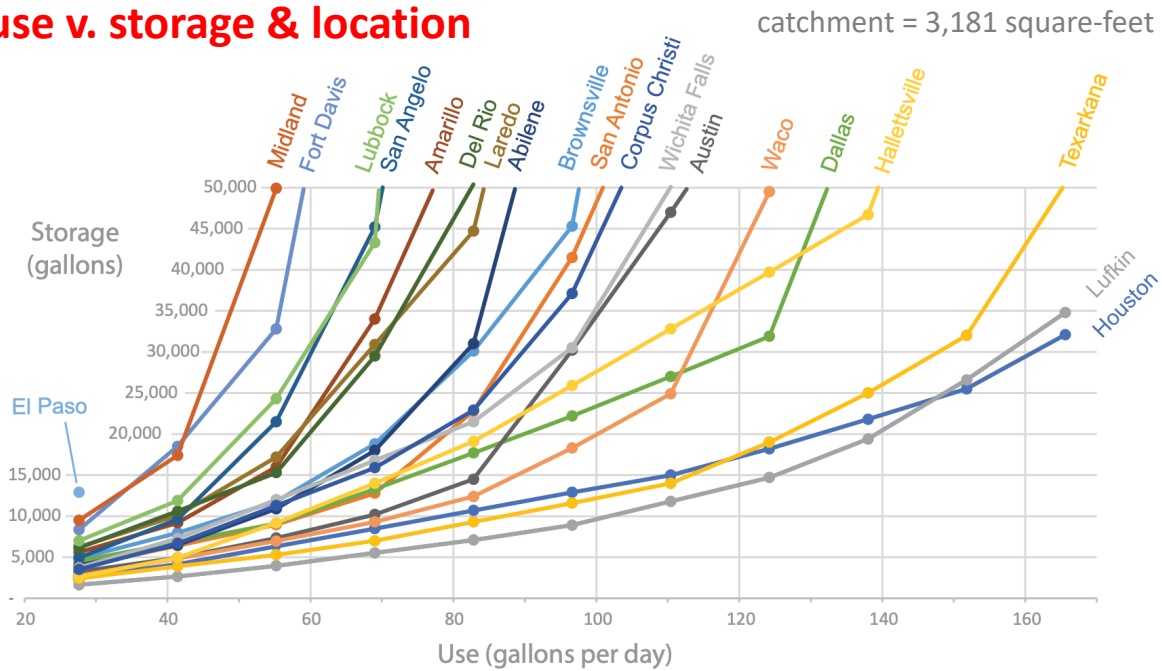
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use v. catchment & location



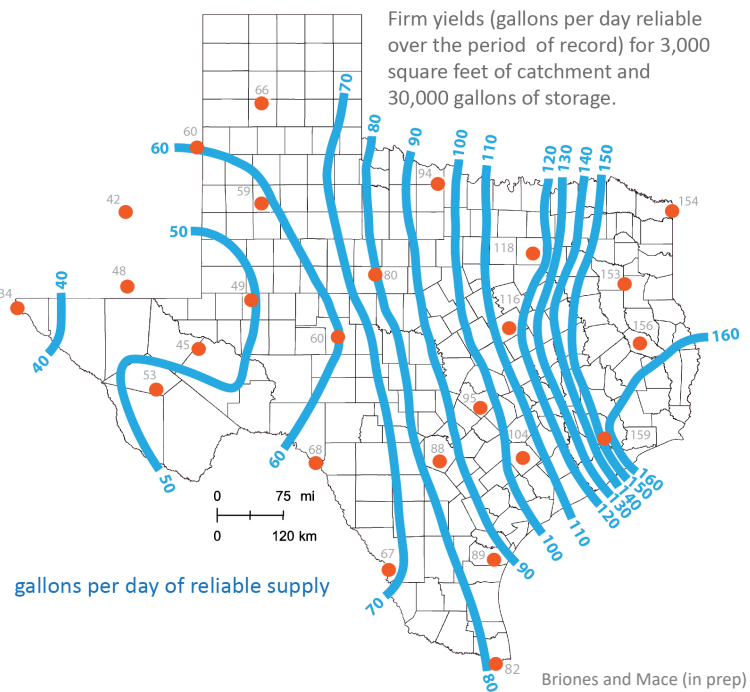
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use v. storage & location



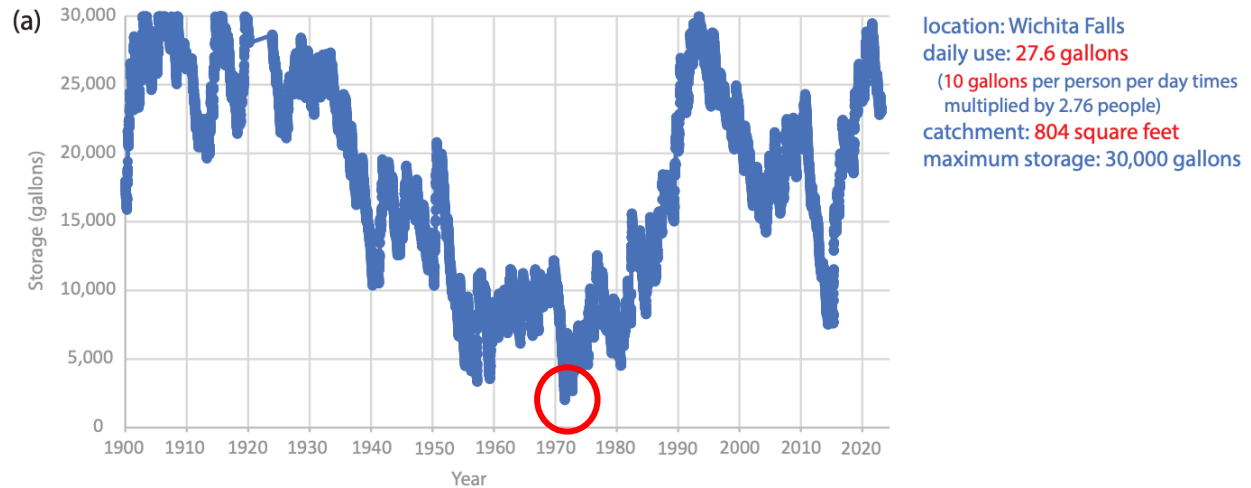
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reliable rainwater harvesting



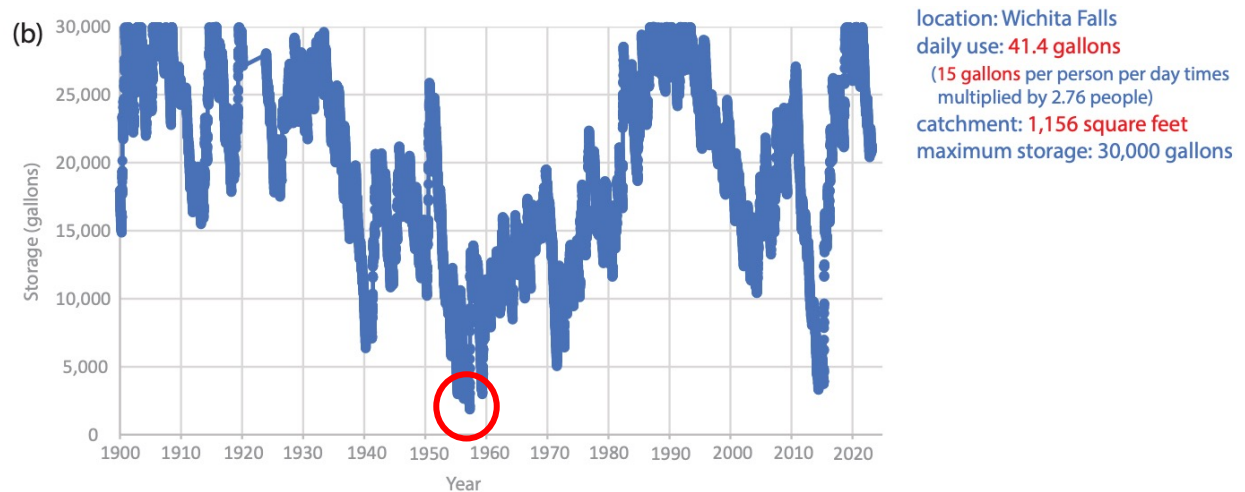
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different droughts for different spouts!



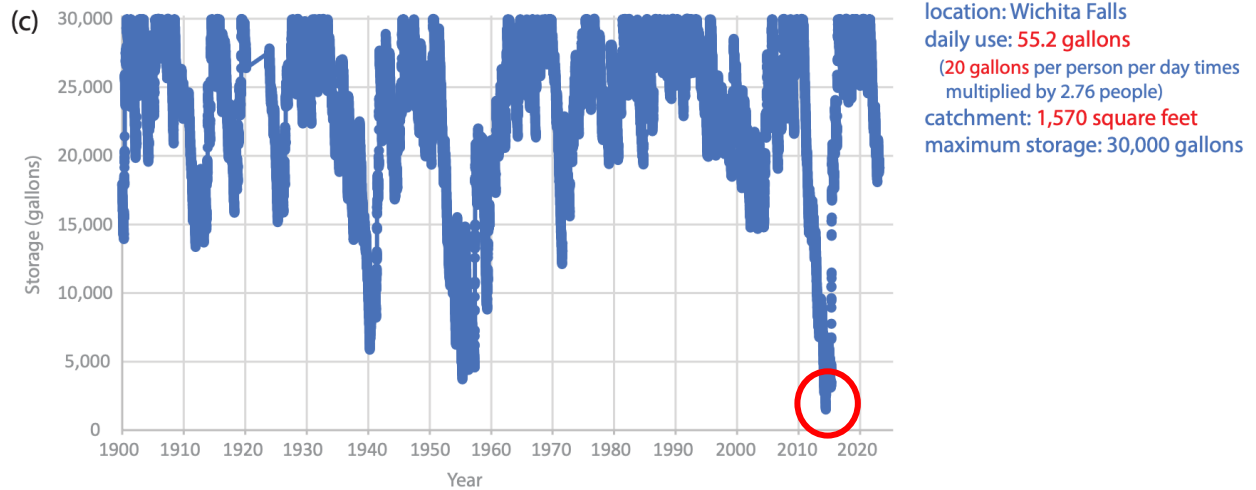
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different droughts for different spouts!



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different droughts for different spouts!



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If every roof in Texas captured rainwater...

- That would be ~600,000 acre-feet of rainwater
 - That's 0.16% of rainfall
 - That's 0.18% of runoff (accounting for evapotranspirative losses)
- But there's ~13 times as much non-roof impervious cover as roof area!
- Which means there's an extra 5.5 million acre-feet of runoff from non-roof impervious cover
- Meaning: **You can collect rainwater guilt-free!**



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next steps

- publish Meadows Center report and RAINFAL sheets
 - doing a quick reanalysis now
- publish peer-reviewed journal article
- look at climate change
- potential future studies:
 - build in a seasonal use component
 - build in condensate as a conjunctive source
 - look at sensitivity to first flush volumes
 - assess how rainwater harvesting (reliable or not) can be resiliently built into water resources for communities
 - PFAS? (per- and polyfluoroalkyl substances)

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- what is rainwater harvesting?
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conclusions

- It's 'easy' to achieve a firm yield for rainwater harvesting in most of Texas
- there's a larger swath of the state that could employ reliable rainwater harvesting than understood
- the drought of record for a rainwater system depends on the rainwater system in addition to rainfall
- high reliability (<100%) may mean frequent water hauling
- rainwater harvesting ain't stealing your surface water!

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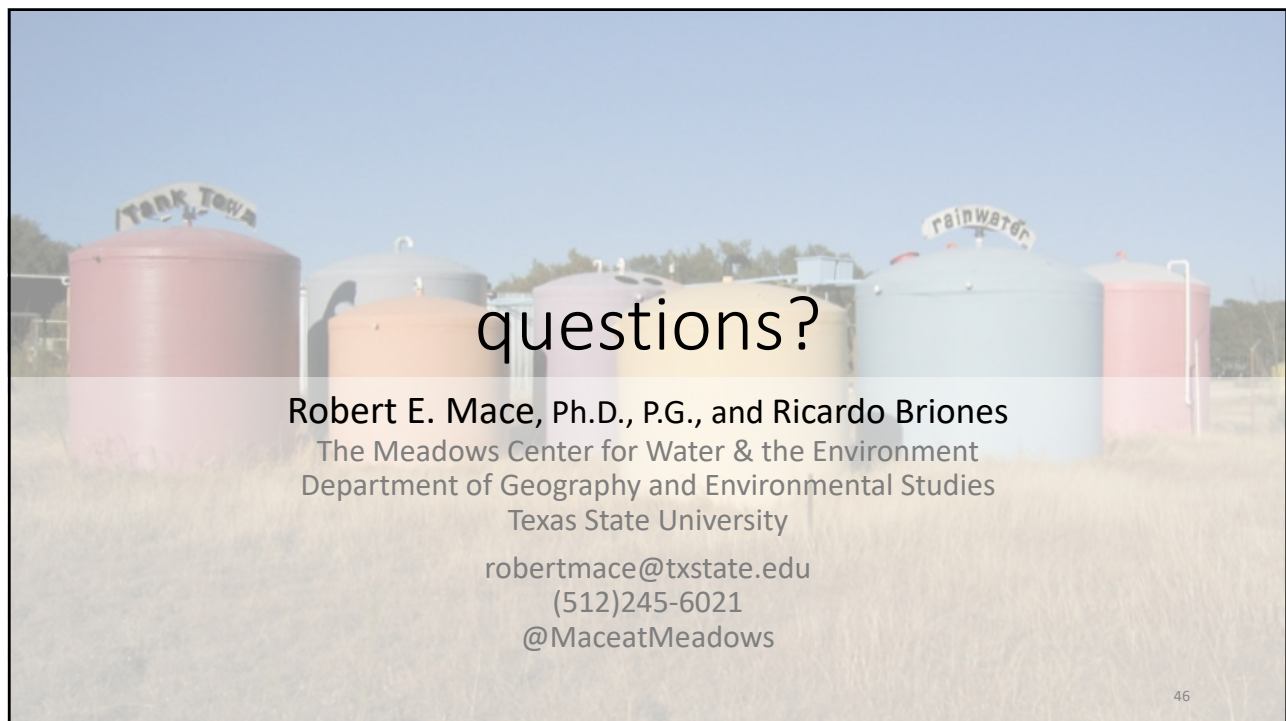
Where are you now on rainwater?

- A. I'm going to do it!
- B. I want to expand my system!
- C. I feel better about rainwater!
- D. This confirms what I was thinking!
- E. I fell asleep!
- F. If you don't show me a picture of your cats, I'm going to eat a bug.

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