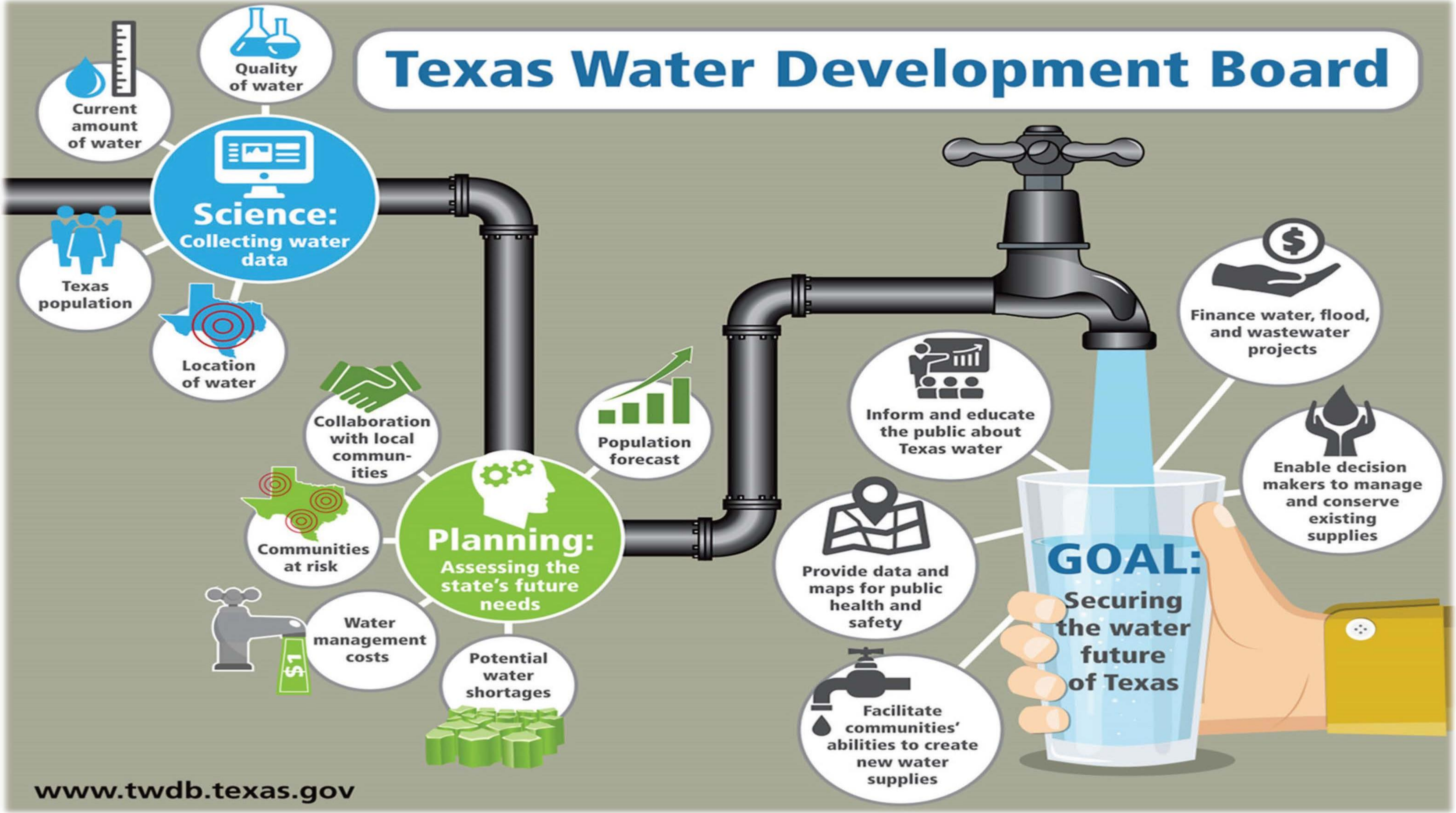
FUTURE WATER FOR TEXAS

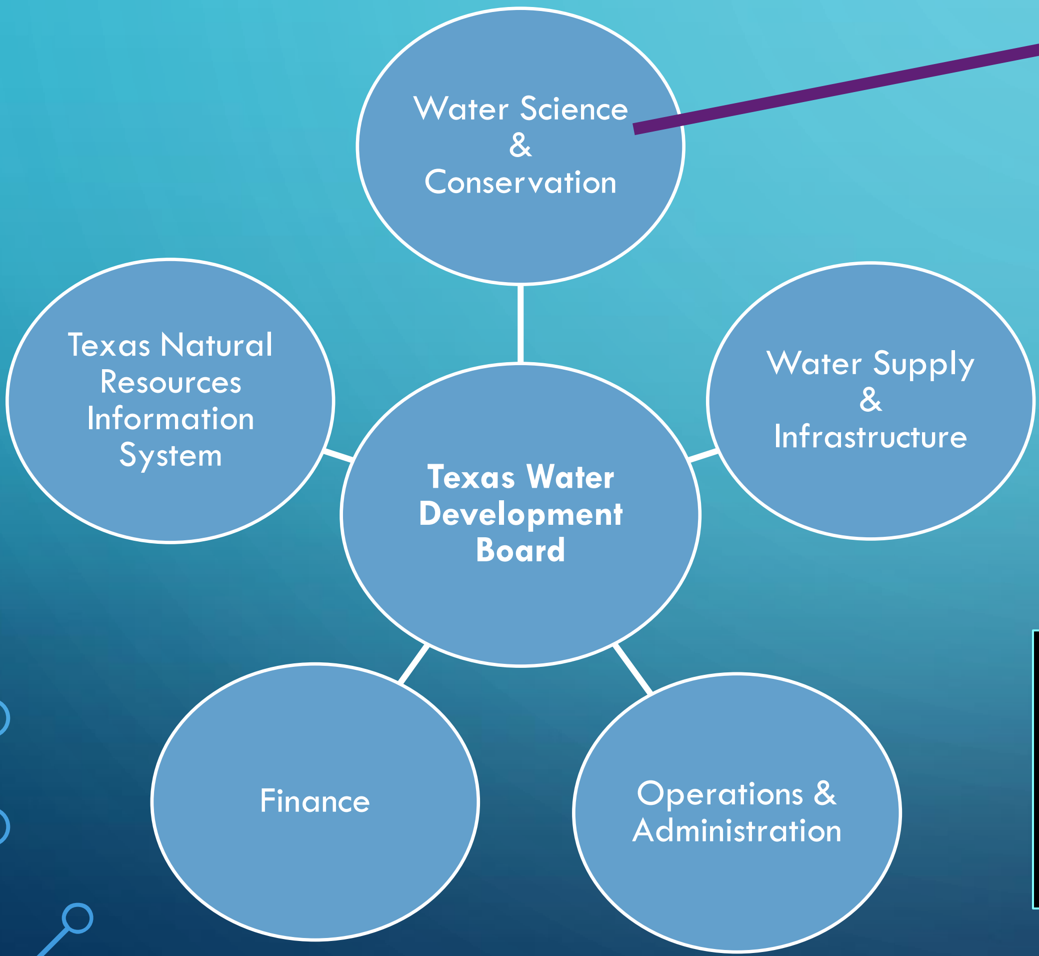
INNOVATIVE WATER TECHNOLOGIES OF TEXAS

ANDREA CROSKREY
TEXAS WATER DEVELOPMENT BOARD

UT-DALLAS GEOSCIENCE SEMINAR
OCTOBER 5, 2023


Texas Water Development Board
Quality of water
Current amount of water
Science: Collecting water data
Texas population
Location of water
Collaboration with local commun-ities
Population forecast
Communities at risk
Planning: Assessing the state's future needs
Water management costs
$1
Potential water shortages
Inform and educate the public about Texas water
Finance water, flood, and wastewater projects
Enable decision makers to manage and conserve existing supplies
Provide data and maps for public health and safety
Facilitate communities' abilities to create new water supplies
GOAL: Securing the water future of Texas
www.twdb.texas.gov

Texas Water Development Board

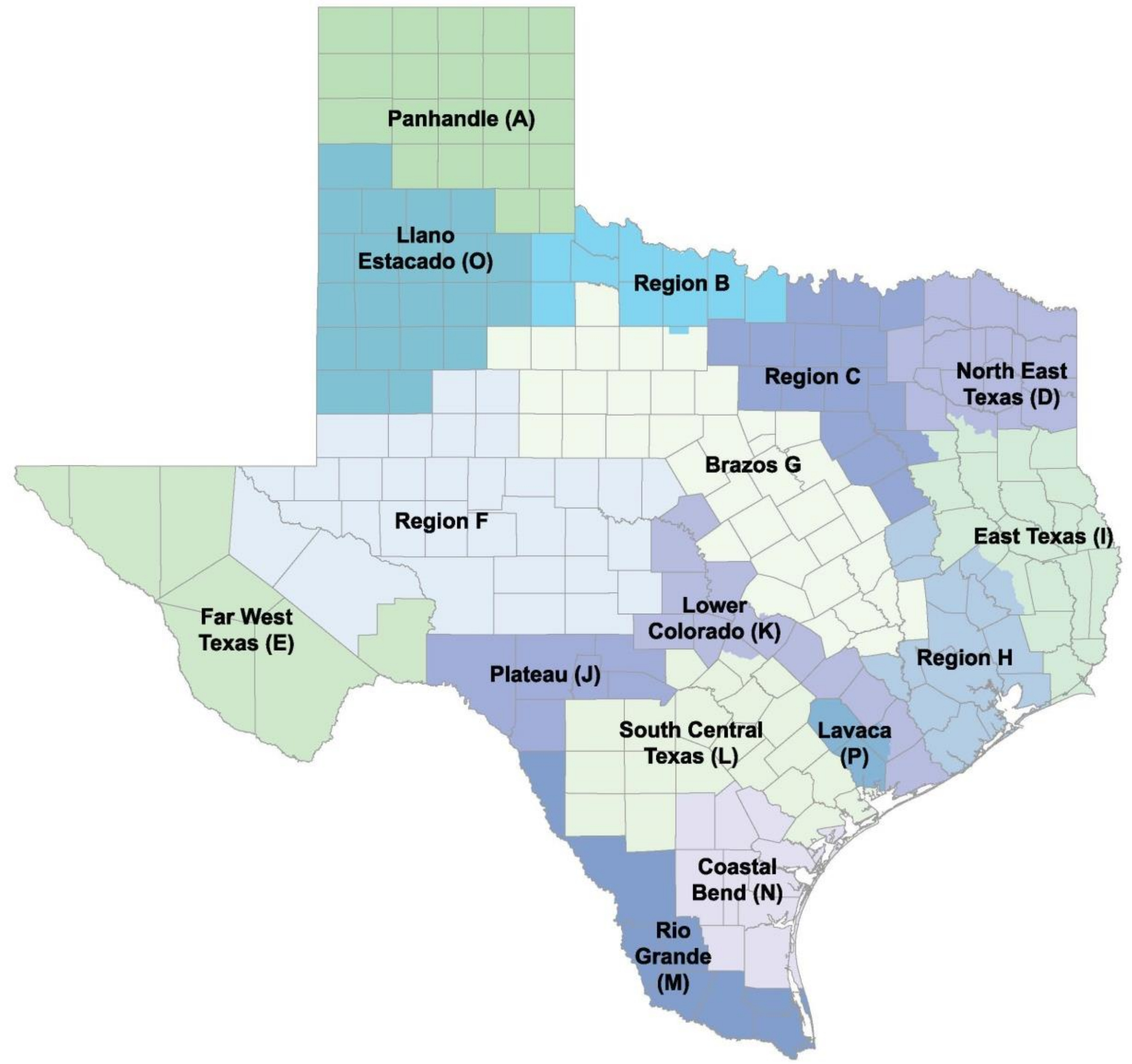


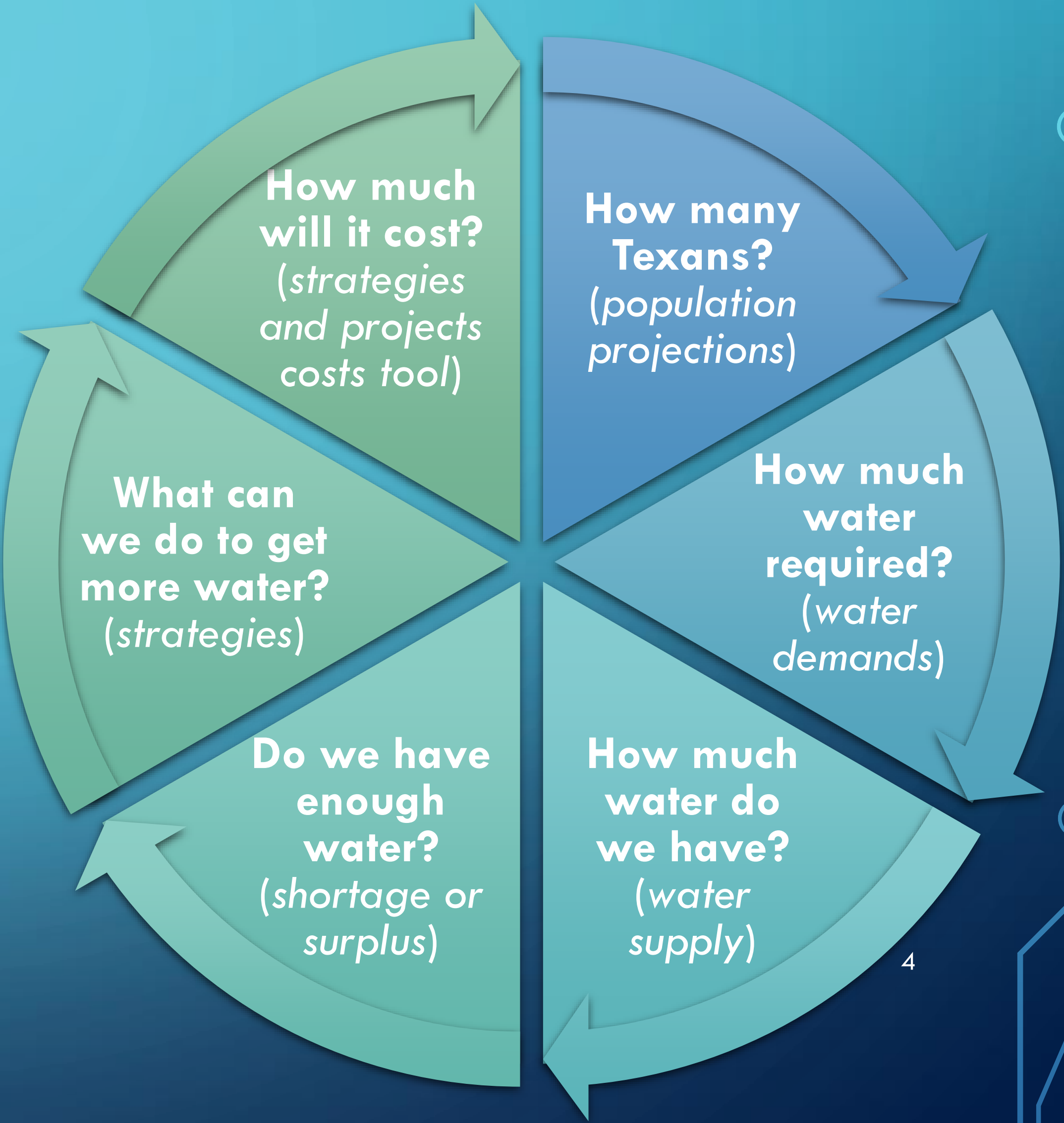
Innovative Water Technologies (IWT)

- Aquifer storage and recovery + aquifer recharge
- Desalination
- Reuse

IWT goal:
"To research, develop, and disseminate information to advance and promote the development and use of alternative water supplies in Texas."

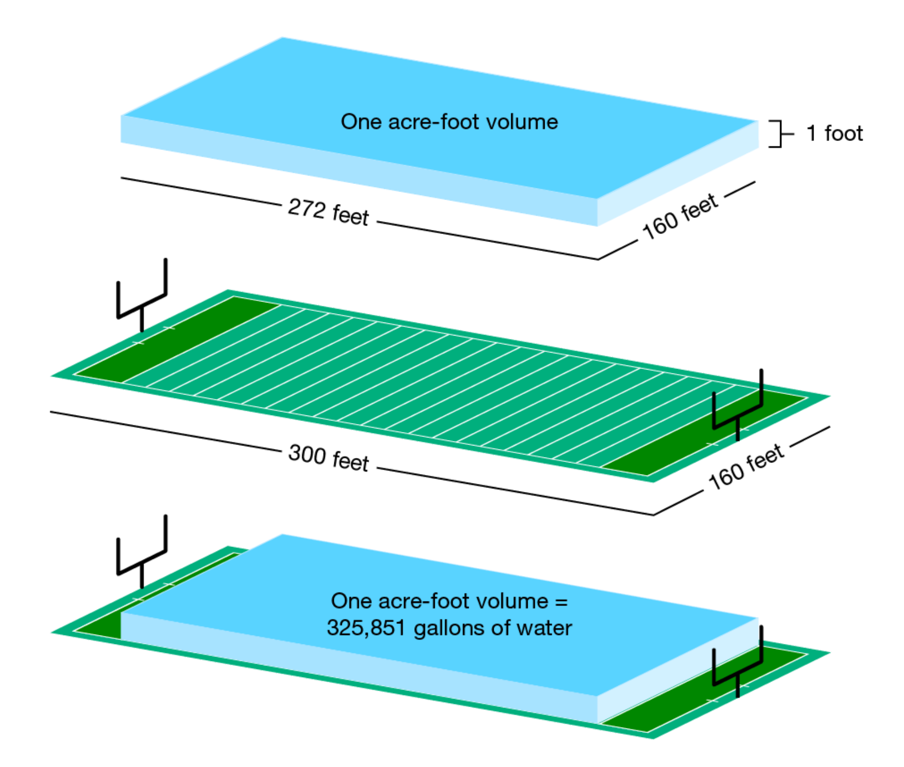
WATER PLANNING





WATER UNITS

- MGD - million gallons per day
- AFY - acre-feet per year
- GPCD - per capita per day
- City of Dallas*:
  - Residential GPCD: 68 gallons (24,820 gallons per year, 0.07617 AFY)
  - Record day of water use in 2022 (July 27th): 655.4 million gallons (2,011 acre-feet)

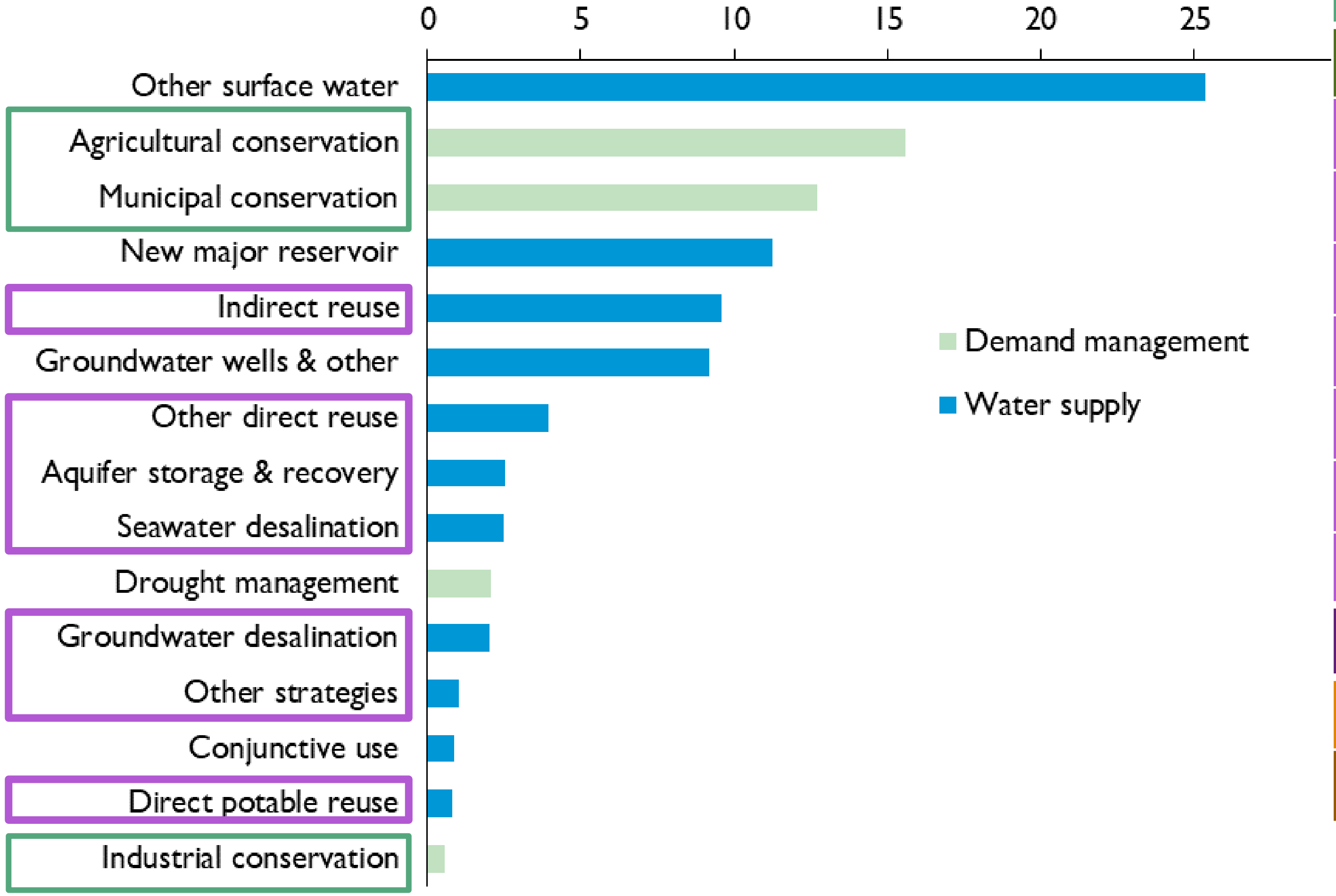


https://nmwd.com/what-is-an-acre-foot/

* 2019 City of Dallas Water Conservation Plan, 2022 Dallas Water Utilities Fact Sheet

CONSERVATION AND INNOVATIVE WATER TECHNOLOGIES (CIWT):

FUTURE WATER SUPPLIES OF TEXAS



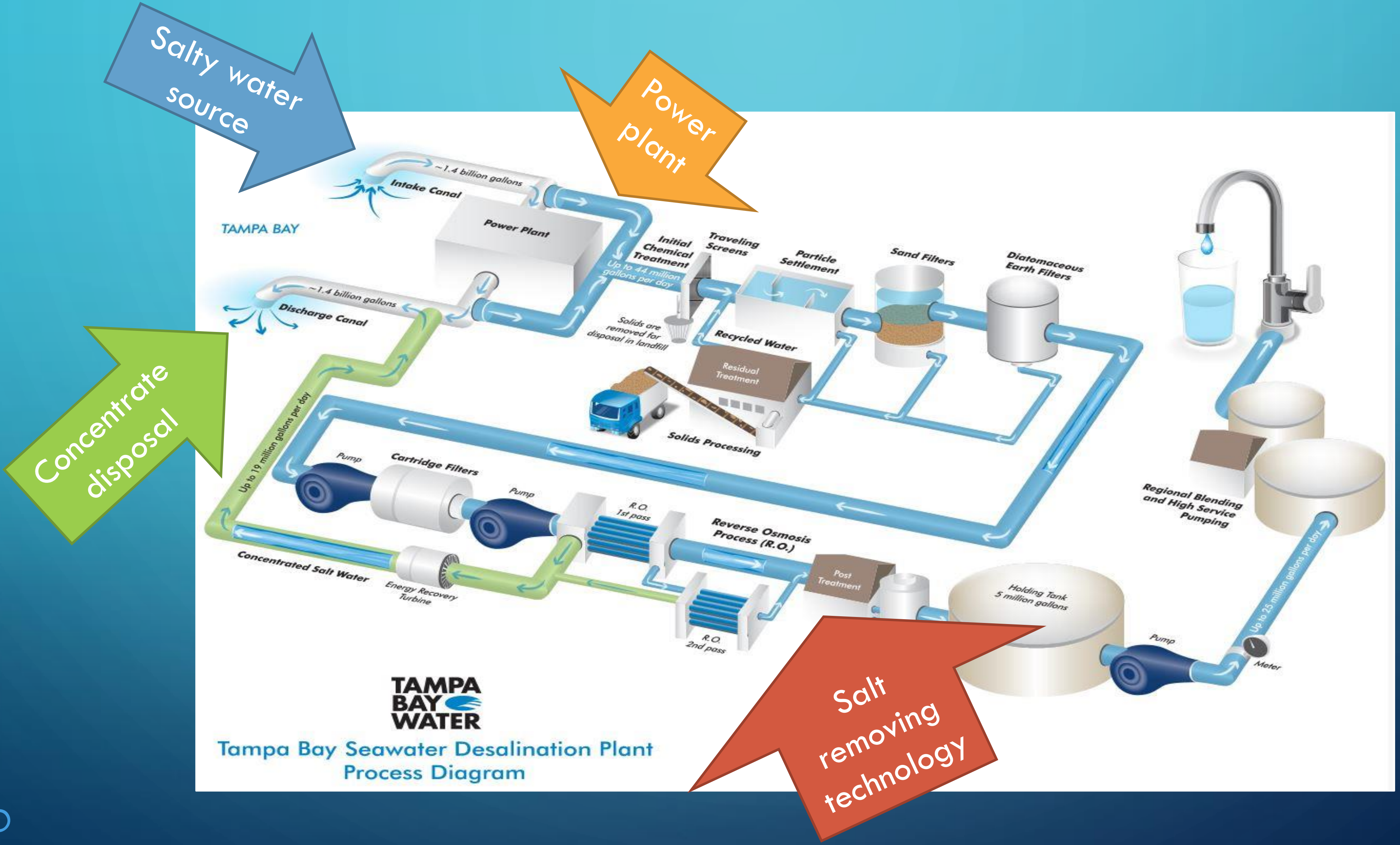
Recommended Strategy Type	Volume (acre-feet)
Agricultural Conservation	1,197,000
Municipal Conservation	977,000
Industrial Conservation	44,000
Rainwater Harvesting	5,000
Conservation Strategies	**2,223,000**
Indirect Reuse	739,000
Other Direct Reuse	305,000
Aquifer Storage and Recovery	193,000
Seawater Desalination	192,000
Groundwater Desalination	157,000
Direct Potable Reuse	62,000
Surface Water Desalination	63,000
IWT Strategies	**1,711,000**
Total CIWT Strategies	**3,934,000**
CIWT percent	**51%**

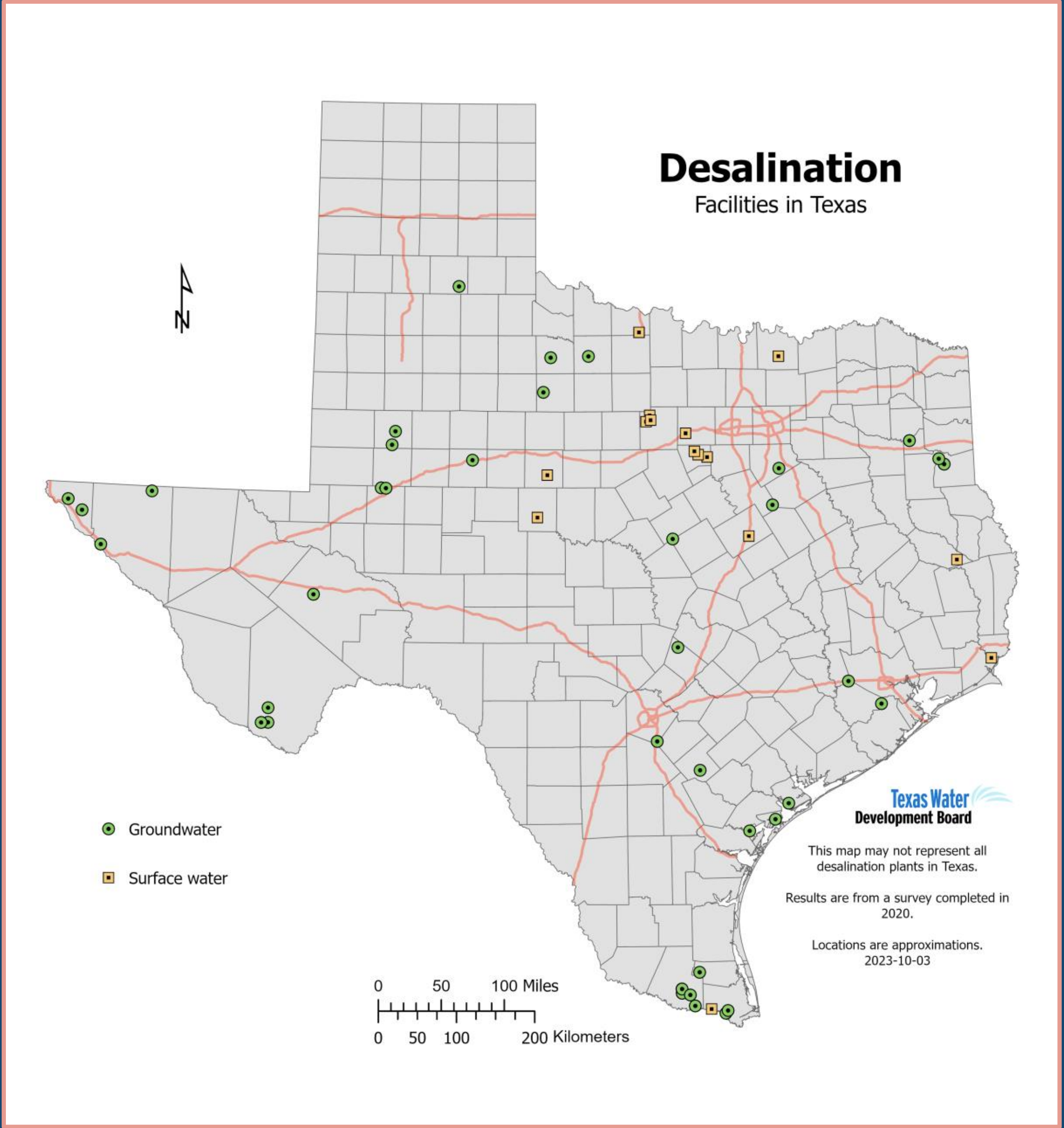
DESALINATION IN TEXAS

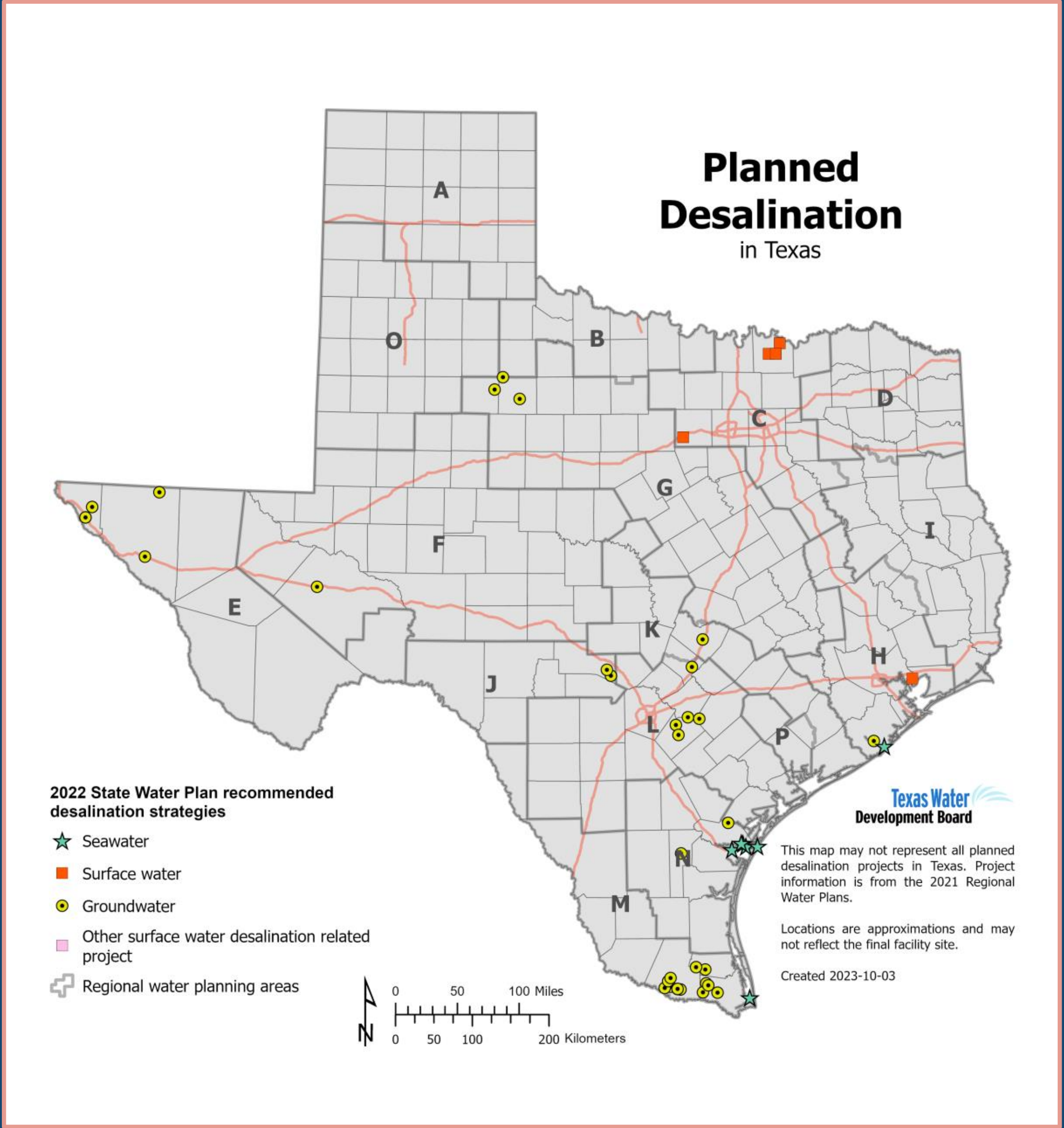
- Currently surface water, groundwater, and produced water (maybe?)
- Seawater in the future?
- Reverse osmosis
- 53 desalination plants in Texas (2020)
  - Total plant capacity 176,013* AFY (157 MGD)
- 50 recommended strategies for 2070 (2022 State Water Plan)
  - 33 groundwater, 7 seawater, 10 surface^
  - 10 of 16 regions
  - 412,000 AFY in 2070, >5% of new water

*includes some advanced treatment of reclaimed water
^includes other strategies that have desalination in the description

HOW TO DESALINATE WATER?




Desalination
Facilities in Texas
Groundwater
Surface water
Texas Water
Development Board
This map may not represent all desalination plants in Texas.
Results are from a survey completed in 2020.
Locations are approximations.
2023-10-03
0 50 100 Miles
0 50 100 200 Kilometers
N


Planned
Desalination
in Texas
A
B
C
D
E
F
G
H
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K
L
M
N
O
P
2022 State Water Plan recommended desalination strategies
Seawater
Surface water
Groundwater
Other surface water desalination related project
Regional water planning areas
Texas Water
Development Board
This map may not represent all planned desalination projects in Texas. Project information is from the 2021 Regional Water Plans.
Locations are approximations and may not reflect the final facility site.
Created 2023-10-03
0 50 100 Miles
0 50 100 200 Kilometers
N

http://www.twdb.texas.gov/innovativewater/reuse/index.asp

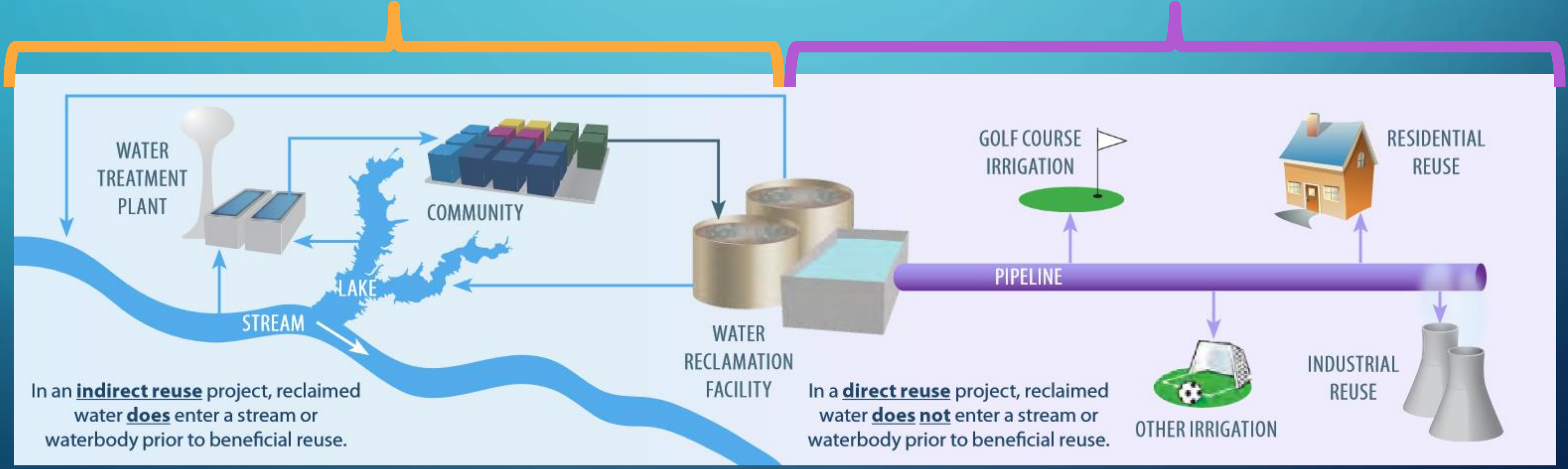
REUSE IN TEXAS

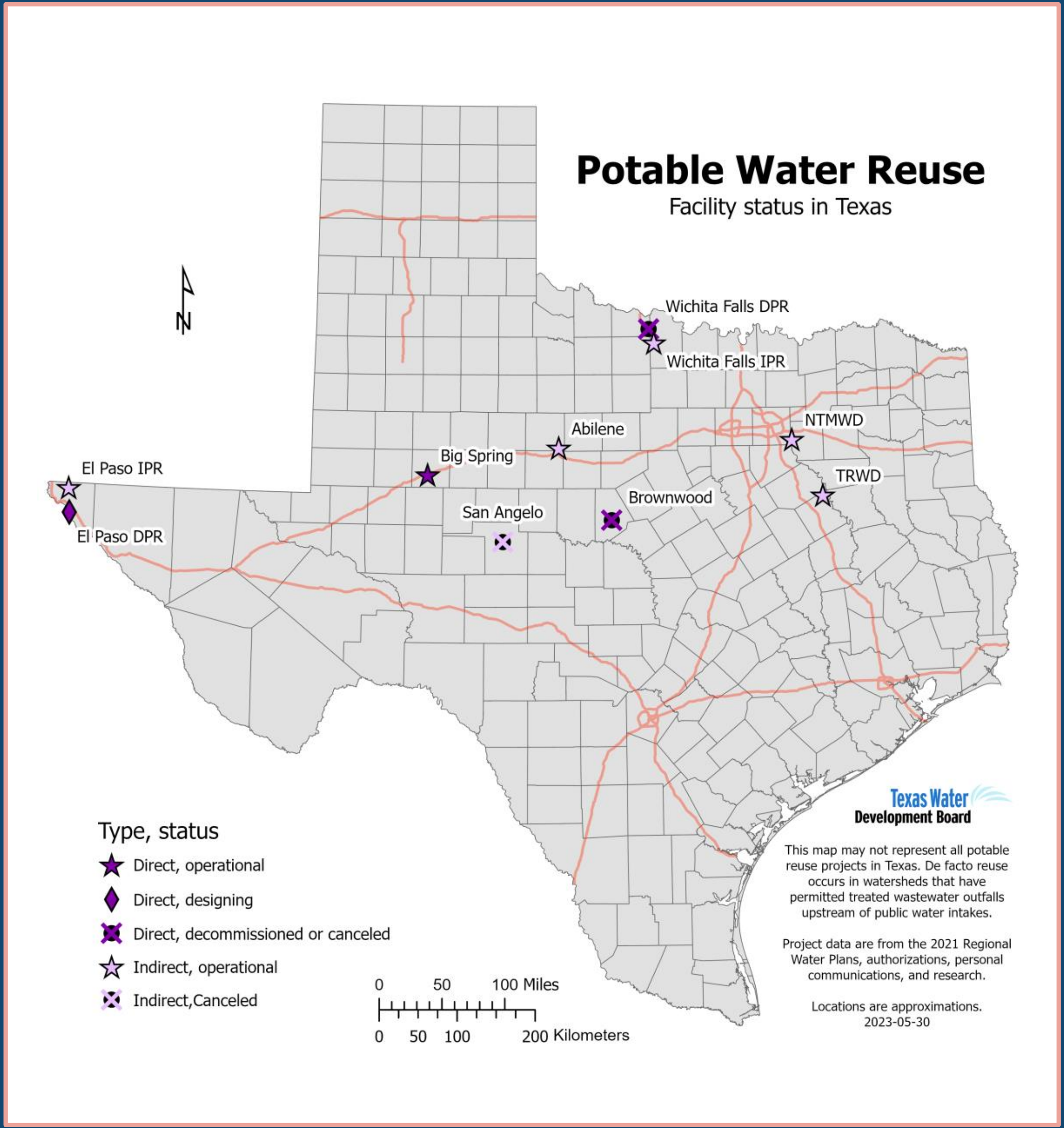
- Fit for purpose treatment: filtration, disinfection
- The number of total facilities not well known
  - 1 Direct Potable Reuse (DPR)
  - 5 In-direct Potable Reuse (IPR)
  - ~620,000 AFY water available in 2022 State Water Plan (>6% of existing supplies, ~1/2 occur in Region C)
- All regions have some type of reuse strategy except for Region P
  - 1.2 million AFY in 2070, ~15% of new supplies
- 19 recommended strategies for DPR
  - DPR, ~62,000 AFY

2 TYPES OF WATER REUSE

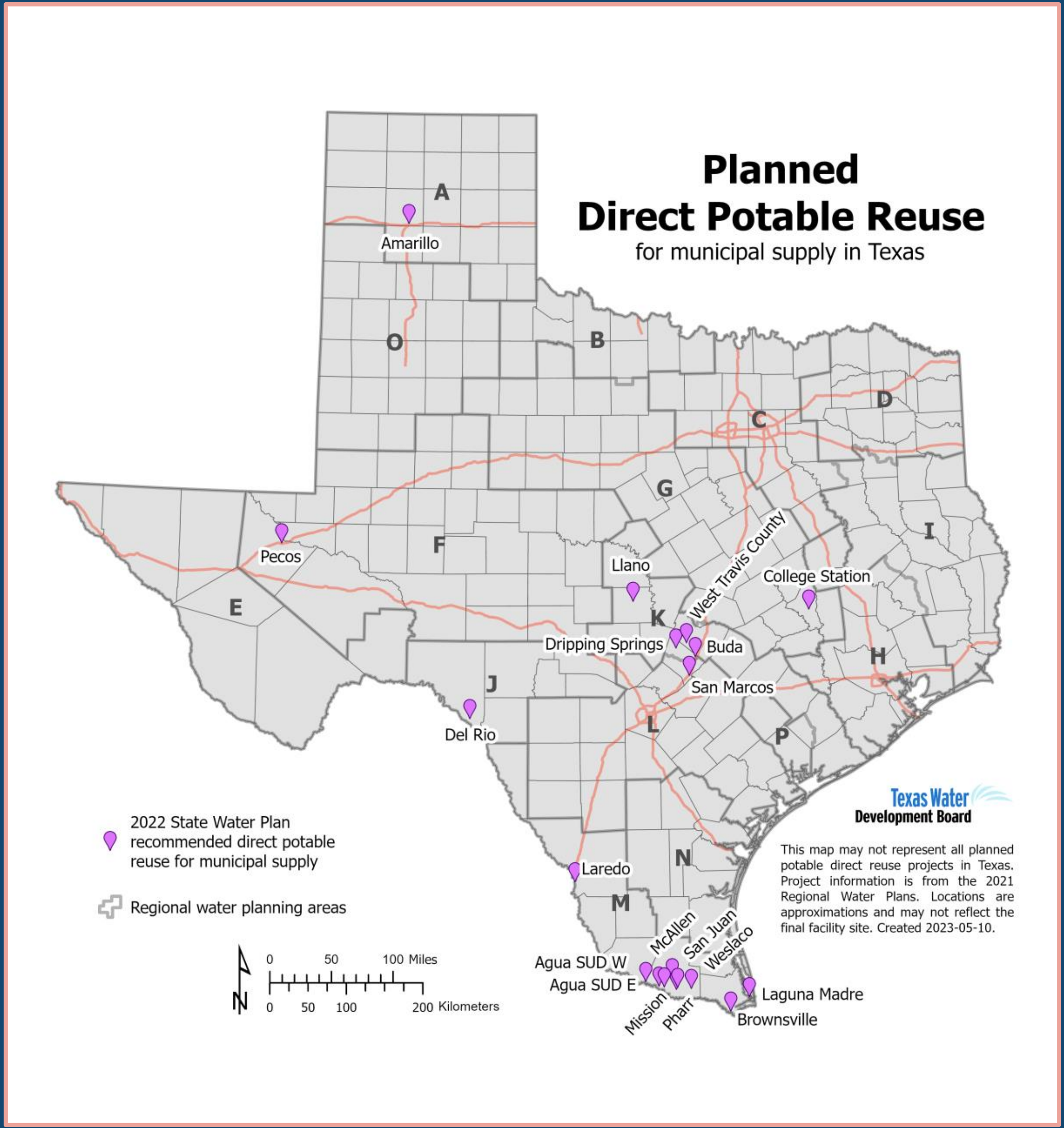
BASED ON INTENDED USE

Indirect (IPR) Direct (DPR)





Potable Water Reuse
Facility status in Texas
Wichita Falls DPR
Wichita Falls IPR
Abilene
NTMWD
Big Spring
El Paso IPR
TRWD
Brownwood
San Angelo
El Paso DPR
Texas Water Development Board
Type, status
Direct, operational
Direct, designing
Direct, decommissioned or canceled
Indirect, operational
Indirect,Canceled
0 50 100 Miles
0 50 100 200 Kilometers
This map may not represent all potable reuse projects in Texas. De facto reuse occurs in watersheds that have permitted treated wastewater outfalls upstream of public water intakes.
Project data are from the 2021 Regional Water Plans, authorizations, personal communications, and research.
Locations are approximations.
2023-05-30

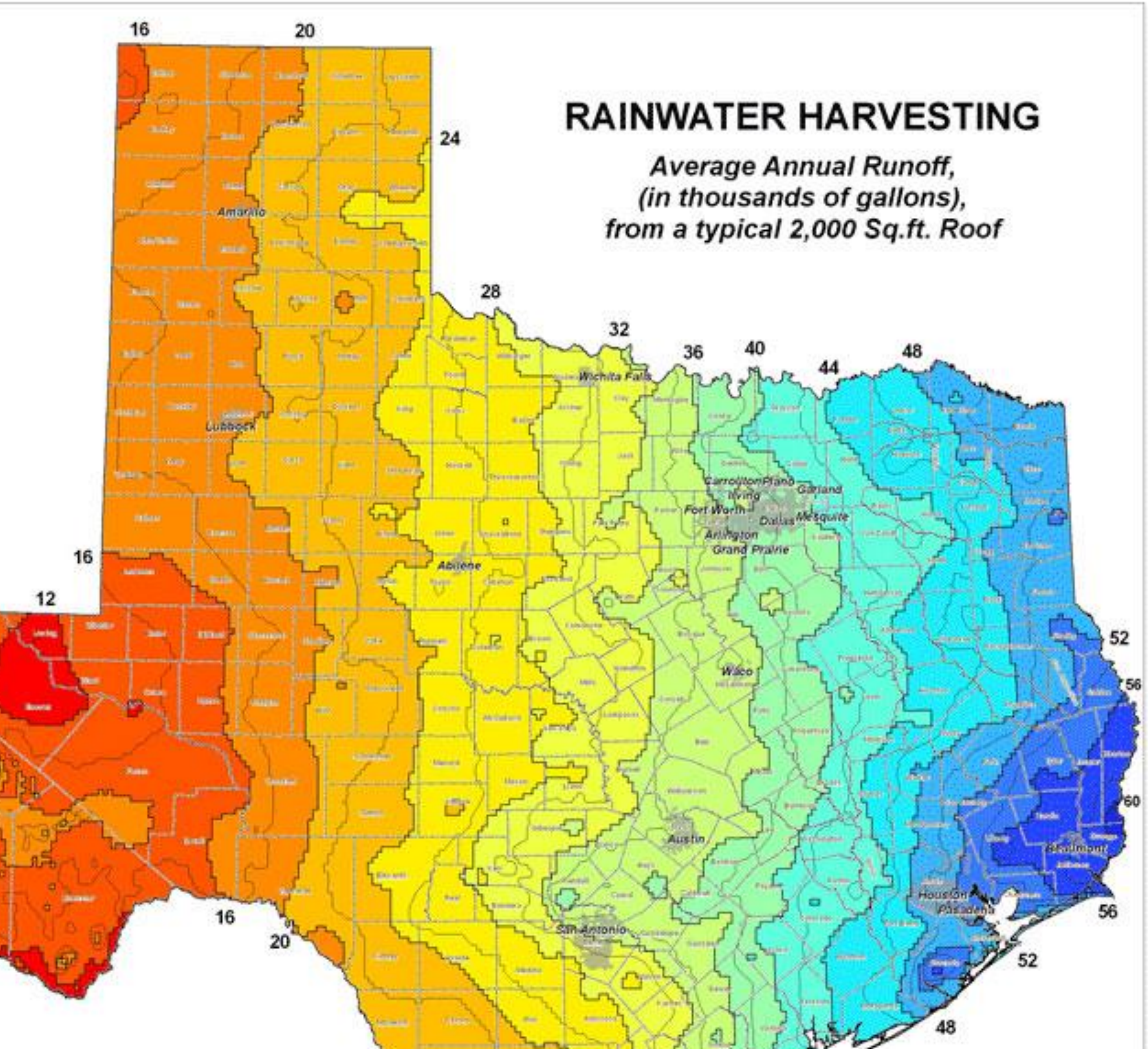


Planned Direct Potable Reuse
for municipal supply in Texas
A
Amarillo
O
B
D
C
G
I
Pecos
F
E
Llano
West Travis County
College Station
K
Dripping Springs
Buda
H
San Marcos
J
Del Rio
L
P
Texas Water Development Board
2022 State Water Plan recommended direct potable reuse for municipal supply
Regional water planning areas
N
Laredo
M
McAllen
San Juan
Weslaco
Agua SUD W
Agua SUD E
Mission
Pharr
Laguna Madre
Brownsville
0 50 100 Miles
0 50 100 200 Kilometers
This map may not represent all planned potable direct reuse projects in Texas. Project information is from the 2021 Regional Water Plans. Locations are approximations and may not reflect the final facility site. Created 2023-05-10.

https://www.twdb.texas.gov/innovativewater/rainwater/index.asp

RAINWATER HARVESTING IN TEXAS

- Used for centuries
- Catchment + storage
  - Inches of rain per year, square feet of catchment, gallons of storage
- TWDB website resources:
  - Potential and guidelines report, manual
  - System size calculator
- A few projects in the state water plan but these are mostly at residential scale.

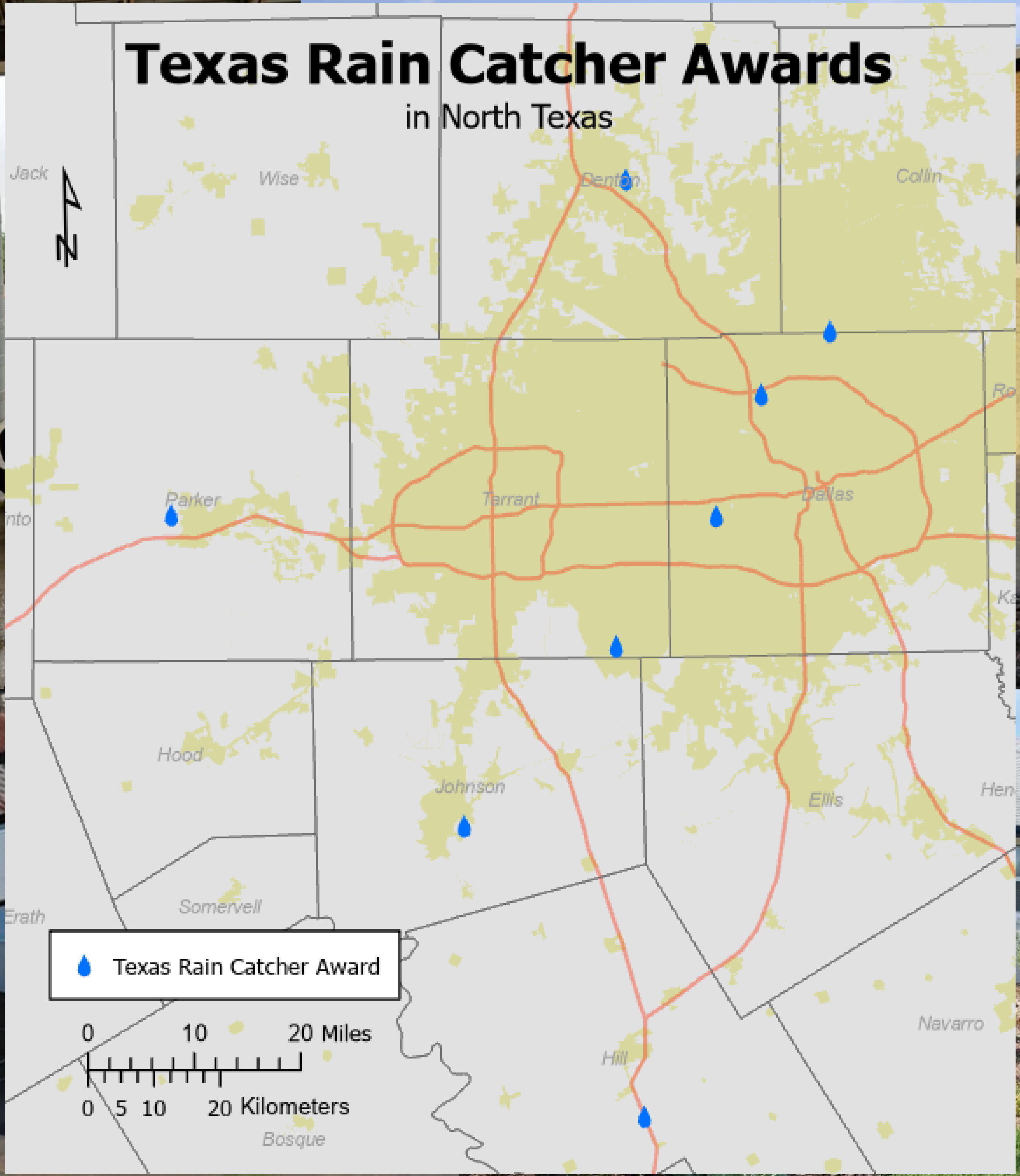


For a single citizen in Dallas:

1. 24,820 gallons per year
2. 2,000 square foot roof
3. Capture between 145-161% of their annual water needs (36,000 to 40,000 gallons per year)

North Texas Rain Catcher Winners:

- Prairielands Groundwater Conservation District Rainwater Harvesting Program (2022)
- Mansfield Water Utilities and TRWD (2021) Cistern
- Upper Trinity GCD & Parker County Livestock (2020)
- **Grand Prairie Armed Forces Reserve Complex (2018)**
- **Herbert Marcus Elementary School (2016)**
- Texas DOT Hill County Safety Rest Area (2014)
- **Texas A&M AgriLife Extension Center in Dallas (2013)**
- Denton County Administrative Complex (2011)



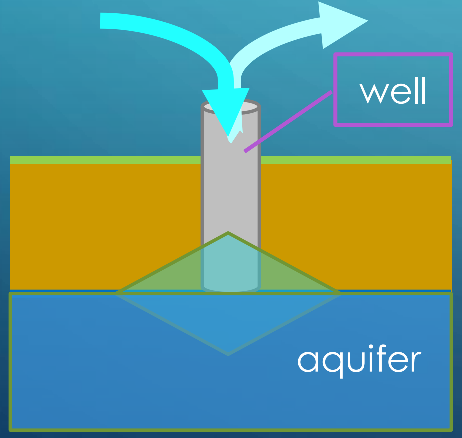
ASR & AR IN TEXAS

- Aquifer storage and recovery & aquifer recharge
- Like a water savings account
- 7 operational (3 ASR, 4 AR), 5 in testing, 4 have authorizations
  - Scales vary greatly
- 10 of 16 regional water planning groups are planning on ASR
  - 193,000 AFY in 2070, 3% of new supply
  - 37 ASR well fields, 3 AR surface infiltration facilities

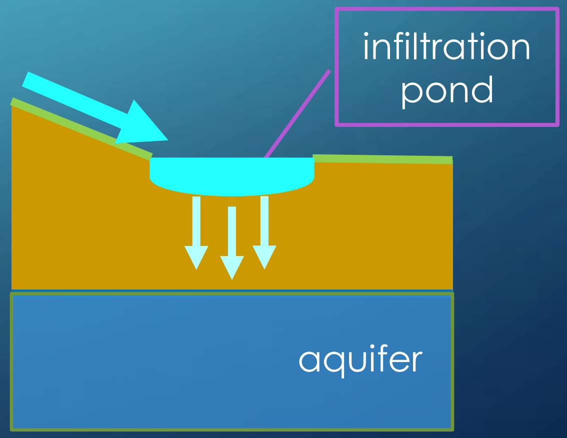
WHAT IS ASR AND AR?

- **Aquifer storage & recovery** (ASR) is using a well to inject water into an aquifer for the purpose of subsequent recovery and beneficial use
- **Aquifer Recharge,** (AR) is the controlled recharge of an aquifer at the surface through various methods such as infiltration basins.

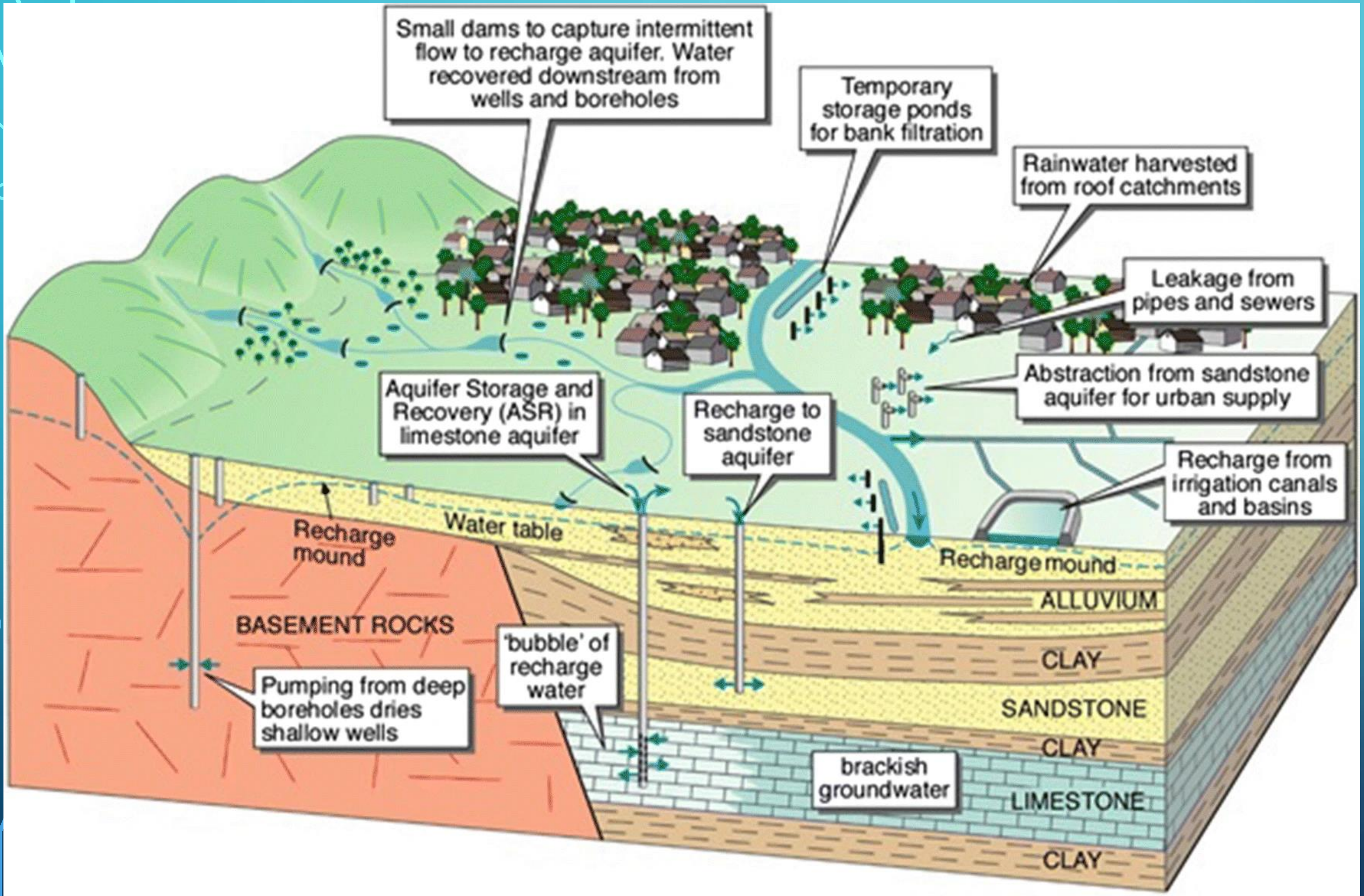
ASR



AR



What is needed for an ASR project?



Needs

- Municipal
- Industrial
- Agricultural
- Environmental

Excess water*

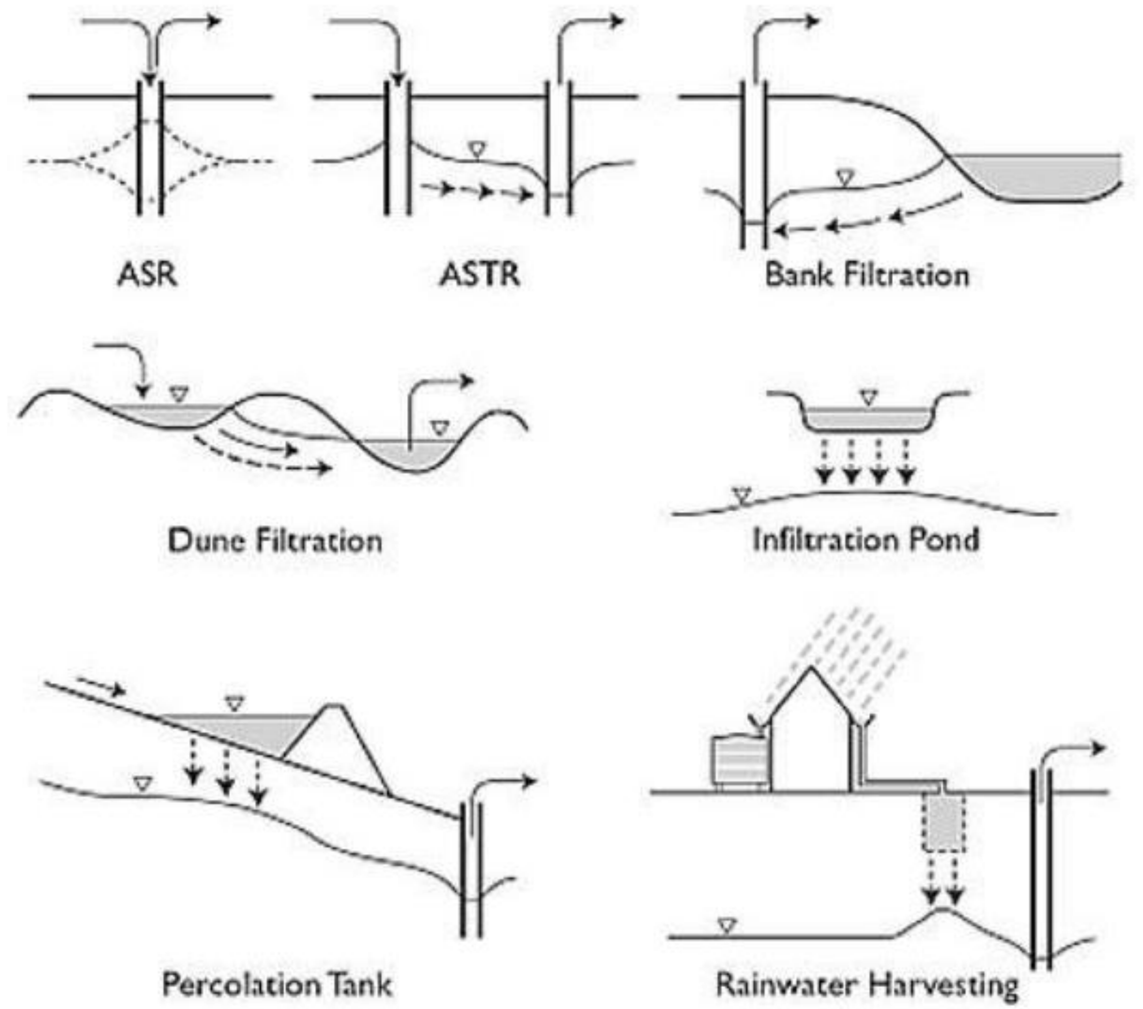
- Surface Water
- Reclaimed Water
- Groundwater

Hydrogeologic characteristics*

- Storage
- Recharge
- Recoverability

***Compatible water quality**

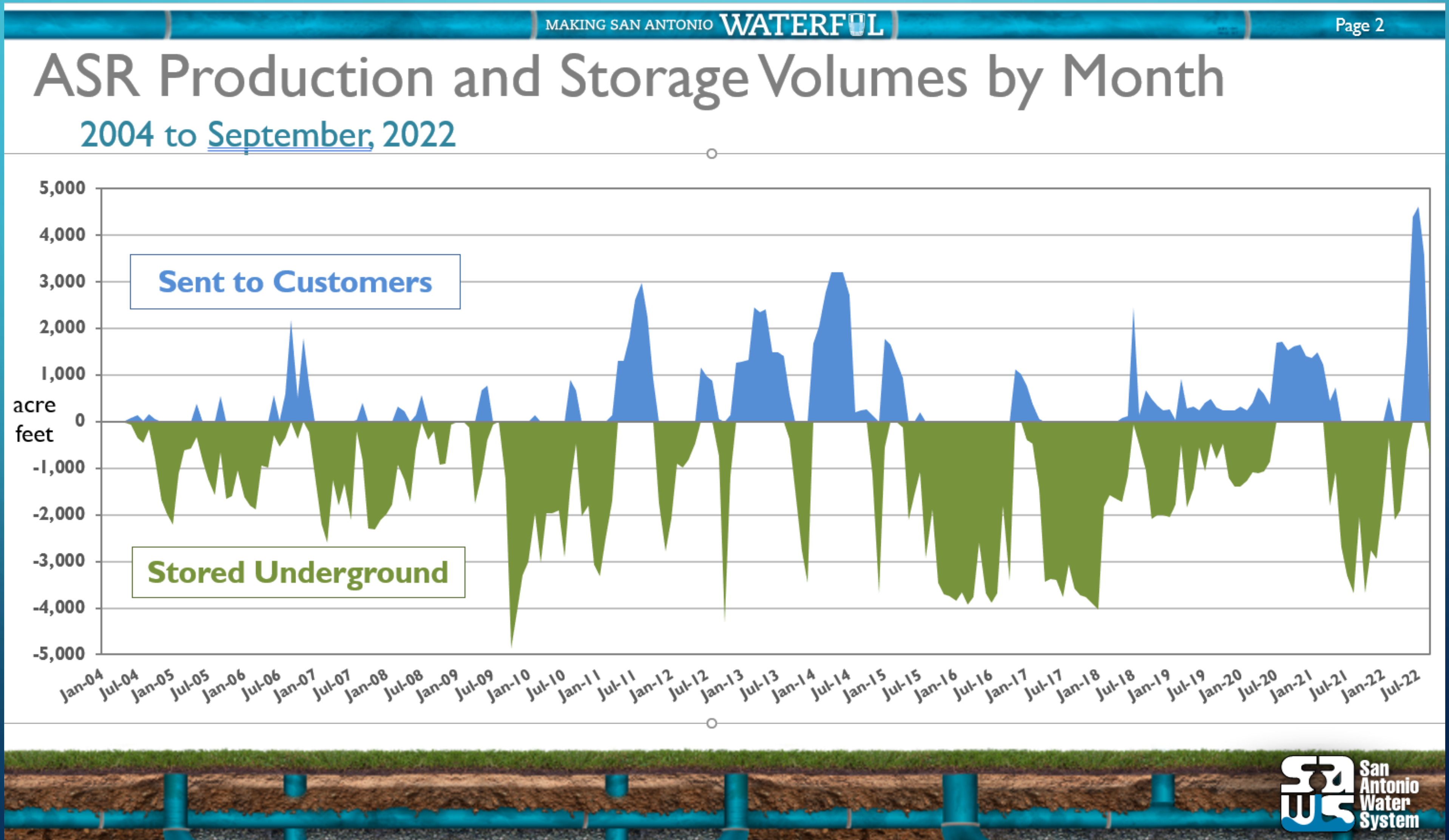
What is needed for an AR project?

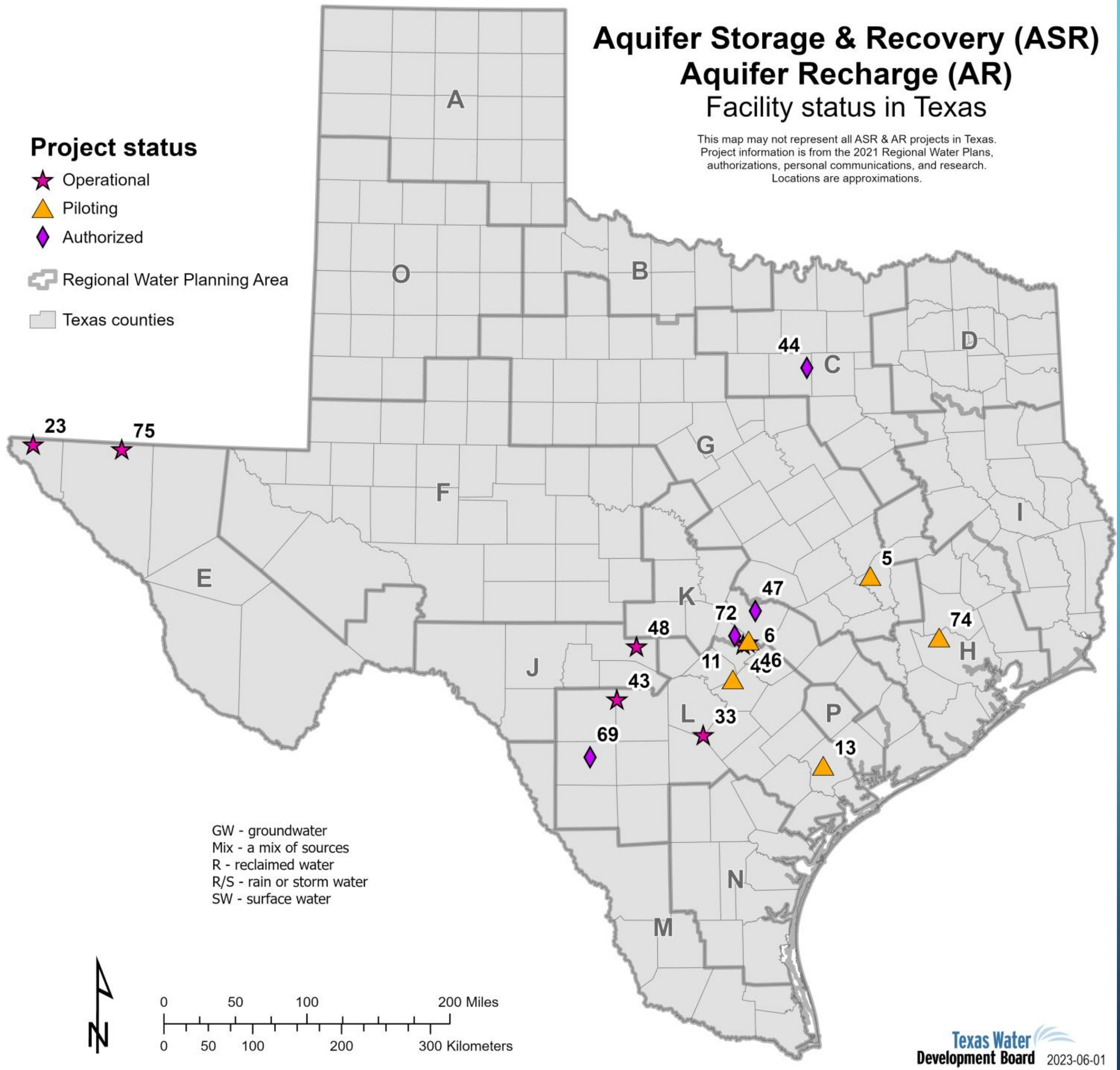


Most common MAR techniques (Gale and Dillon 2005) ASR: Aquifer Storage and Recovery; ASTR: Aquifer Storage Transfer and Recovery

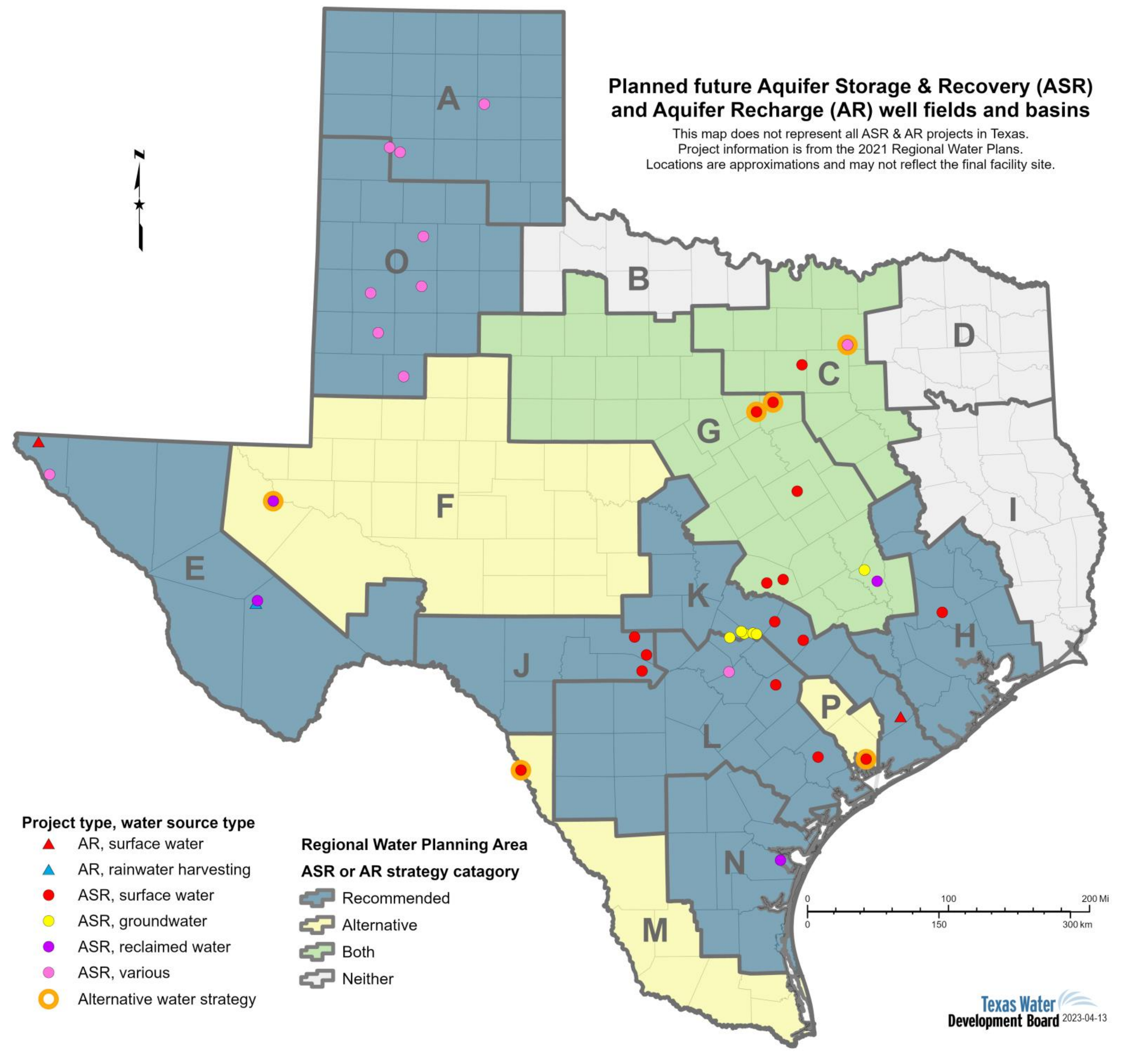
- Spreading methods
  - Infiltrations ponds or basins
  - Flooding
  - Ditch or furrow development
  - Irrigation
- Induced bank infiltration
- Channel modification or diversion
  - Recharge dams
  - Sand dams
  - Channel spreading
- Runoff harvesting
  - Barriers
  - Trenches
- Reclaimed water reuse
  - Treatment effluent
  - Wastewater

ASR
A WATER SAVINGS ACCOUNT





ID	Label name	Status	Source	Type
5	City of Bryan	Piloting	GW	ASR
6	City of Buda	Piloting	GW	ASR
11	City of New Braunfels	Piloting	Mix	ASR
13	City of Victoria	Piloting	SW	ASR
23	El Paso Water Utilities, reuse recharge	Operational	R	AR
33	San Antonio Water System	Operational	GW	ASR
43	Seco Sinkhole	Operational	SW	AR
44	Tarrant Regional Water District	Authorized	SW	ASR
45	Ruby Ranch Water Supply Corporation	Operational	GW	ASR
46	Onion Creek recharge structures	Operational	SW	AR
47	residential rainwater harvesting	Authorized	R/S	AR
48	City of Kerrville	Operational	SW	ASR
69	Wintergarden GCD	Authorized	SW	AR
72	Driftwood Municipal Management District	Authorized	R/S	AR
74	Harris County infiltration basin	Piloting	R/S	AR
75	Dell City flood dams	Operational	R/S	AR


Planned future Aquifer Storage & Recovery (ASR) and Aquifer Recharge (AR) well fields and basins
This map does not represent all ASR & AR projects in Texas.
Project information is from the 2021 Regional Water Plans.
Locations are approximations and may not reflect the final facility site.
N
A
B
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L
M
N
O
P
Project type, water source type
AR, surface water
AR, rainwater harvesting
ASR, surface water
ASR, groundwater
ASR, reclaimed water
ASR, various
Alternative water strategy
Regional Water Planning Area
ASR or AR strategy catagory
Recommended
Alternative
Both
Neither
0
100
200 Mi
0
150
300 km
Texas Water Development Board
2023-04-13

THE INTERSECTION OF INNOVATIVE WATER TECHNOLOGIES AND HYDROGEOLOGY

STRATA FOR STORAGE

SOURCE WATER SUPPLY

INFLUENCES HYDROLOGIC CYCLE

AS A GEOLOGIST, WHAT IS MY ROLE?

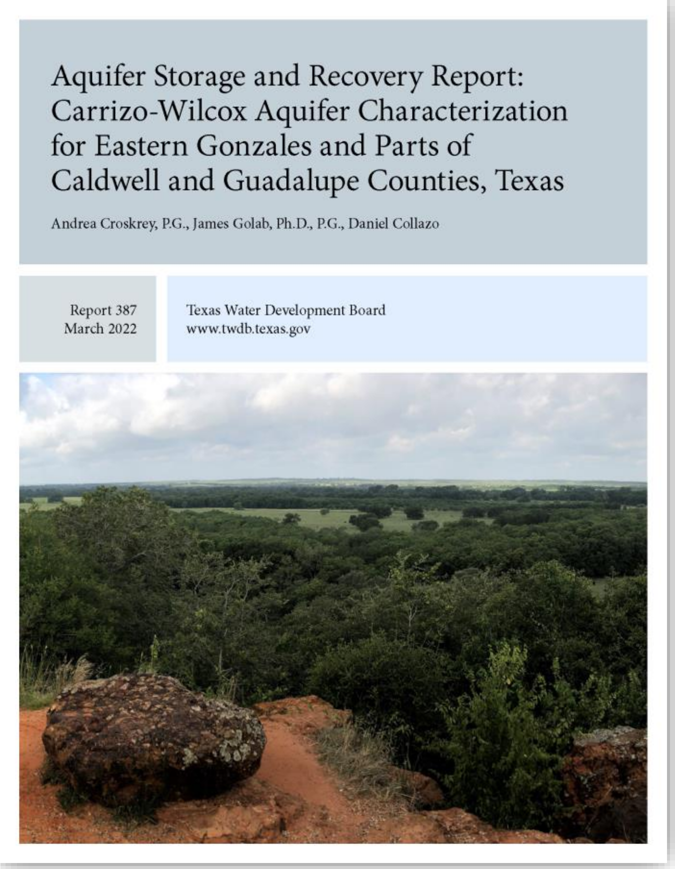
STUDIES

TECHNICAL SUPPORT

OUTREACH

Aquifer Storage and Recovery Report: Carrizo-Wilcox Aquifer Characterization

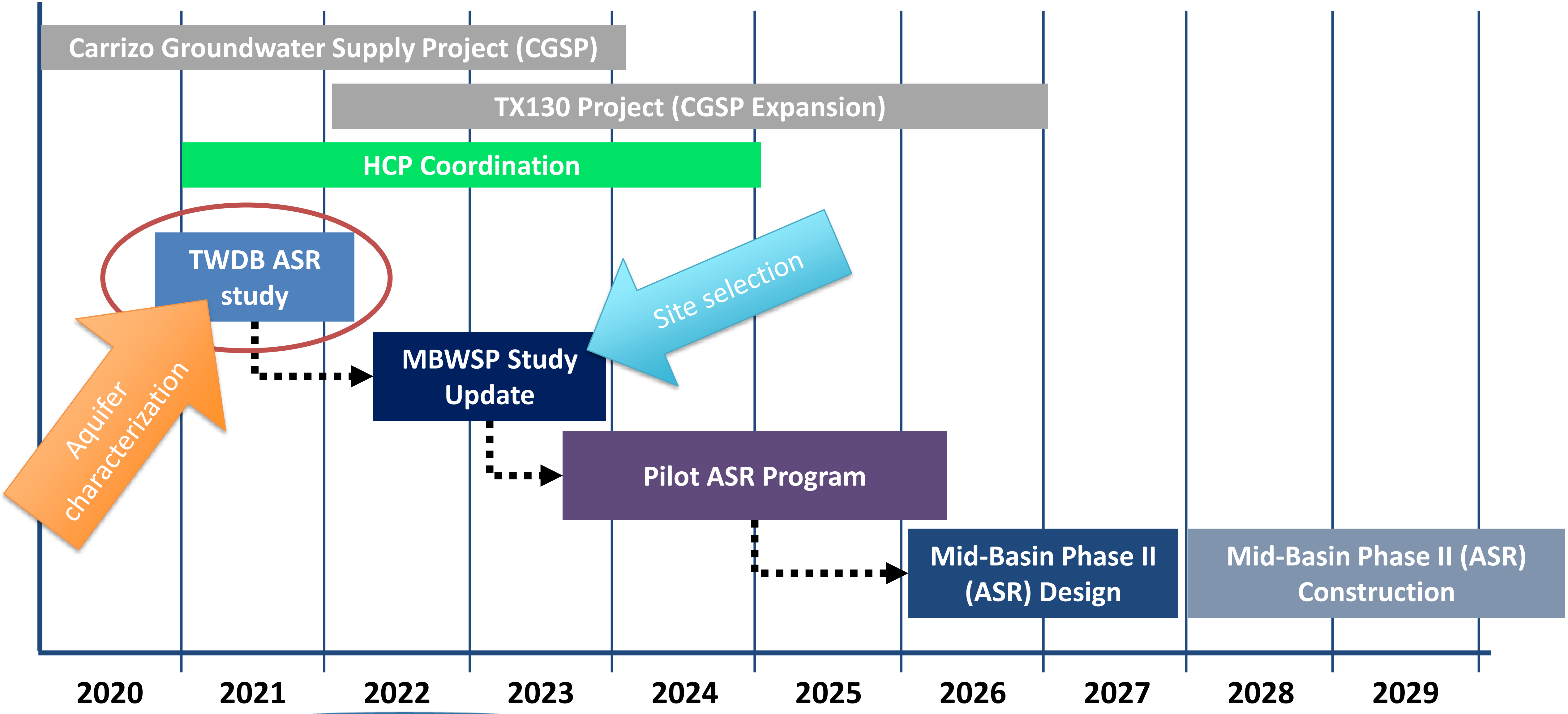
Eastern Gonzales and Parts of Caldwell and Guadalupe Counties, Texas



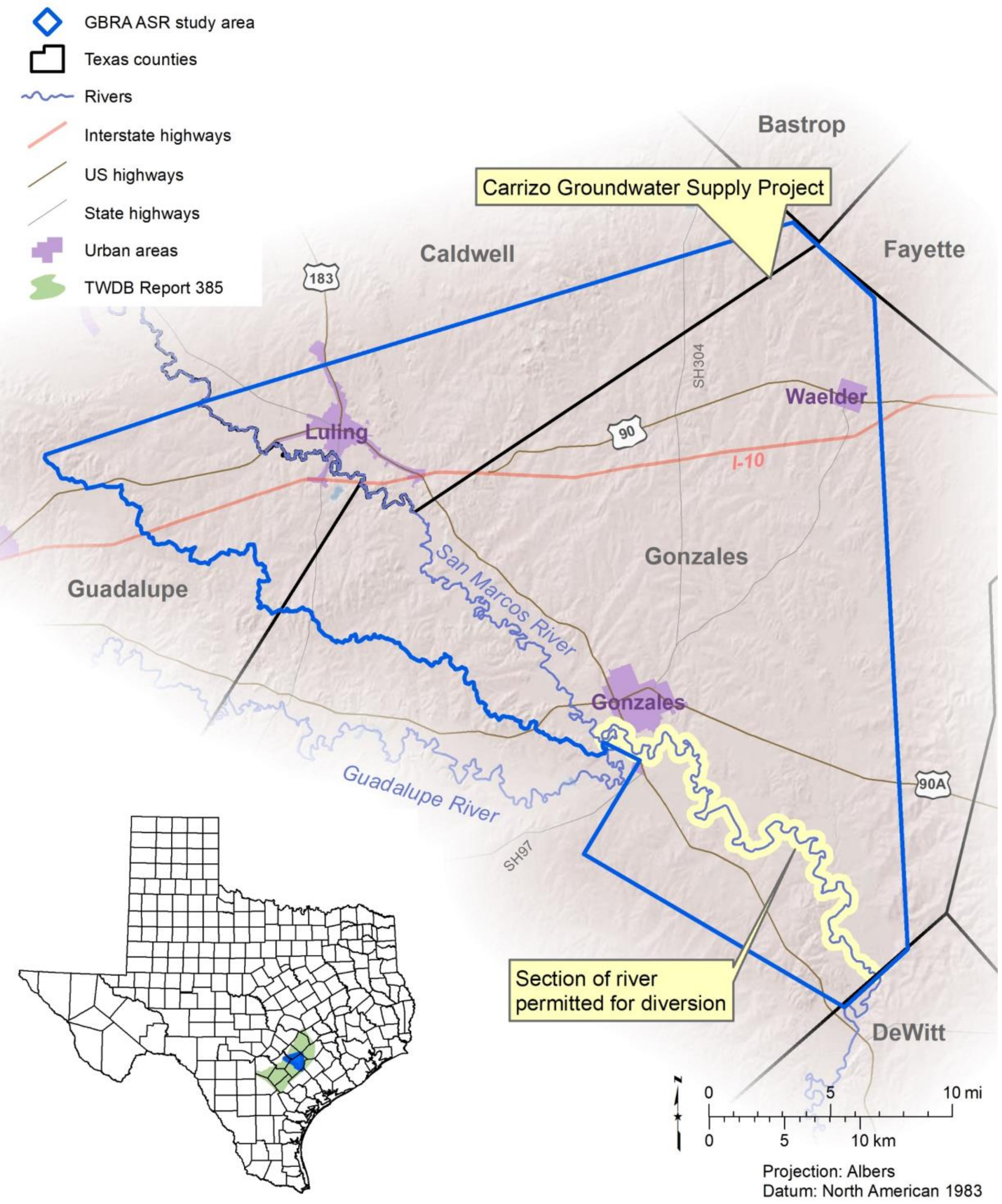
- Introduction
- Study methods and results
- Discussion and conclusions

https://www.twdb.texas.gov/innovativewater/asr/projects/GBRA/index.asp

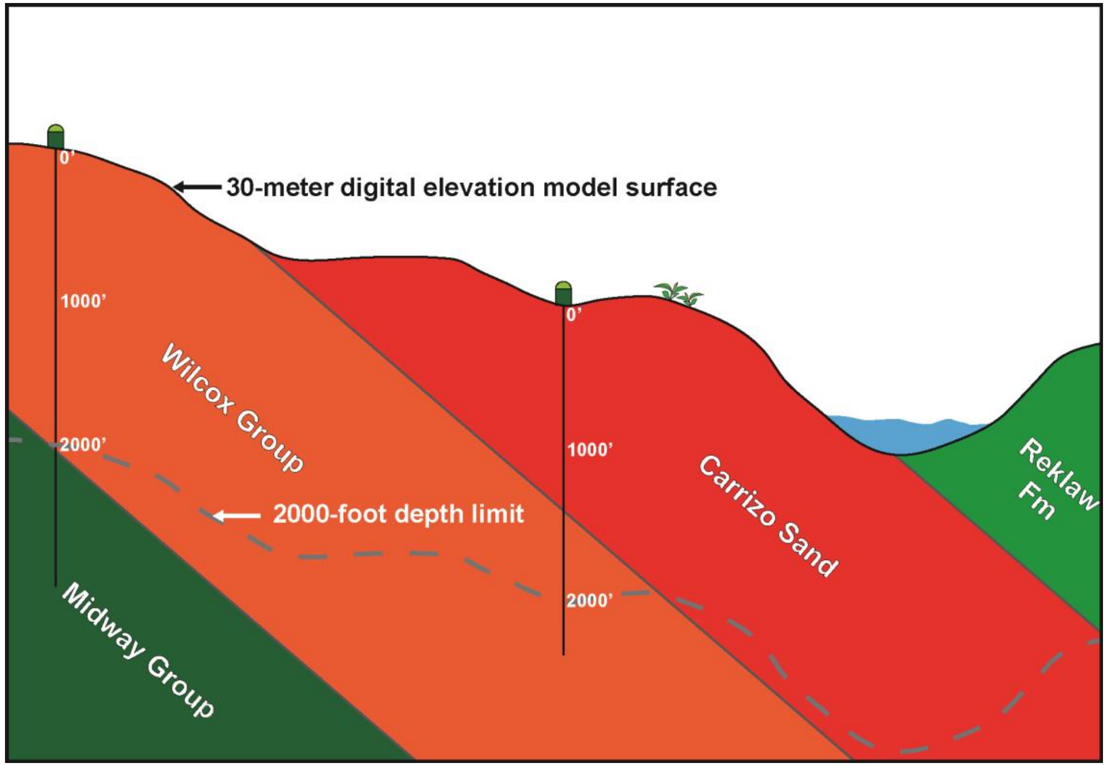
Mid-Basin Water Supply Project Schedule

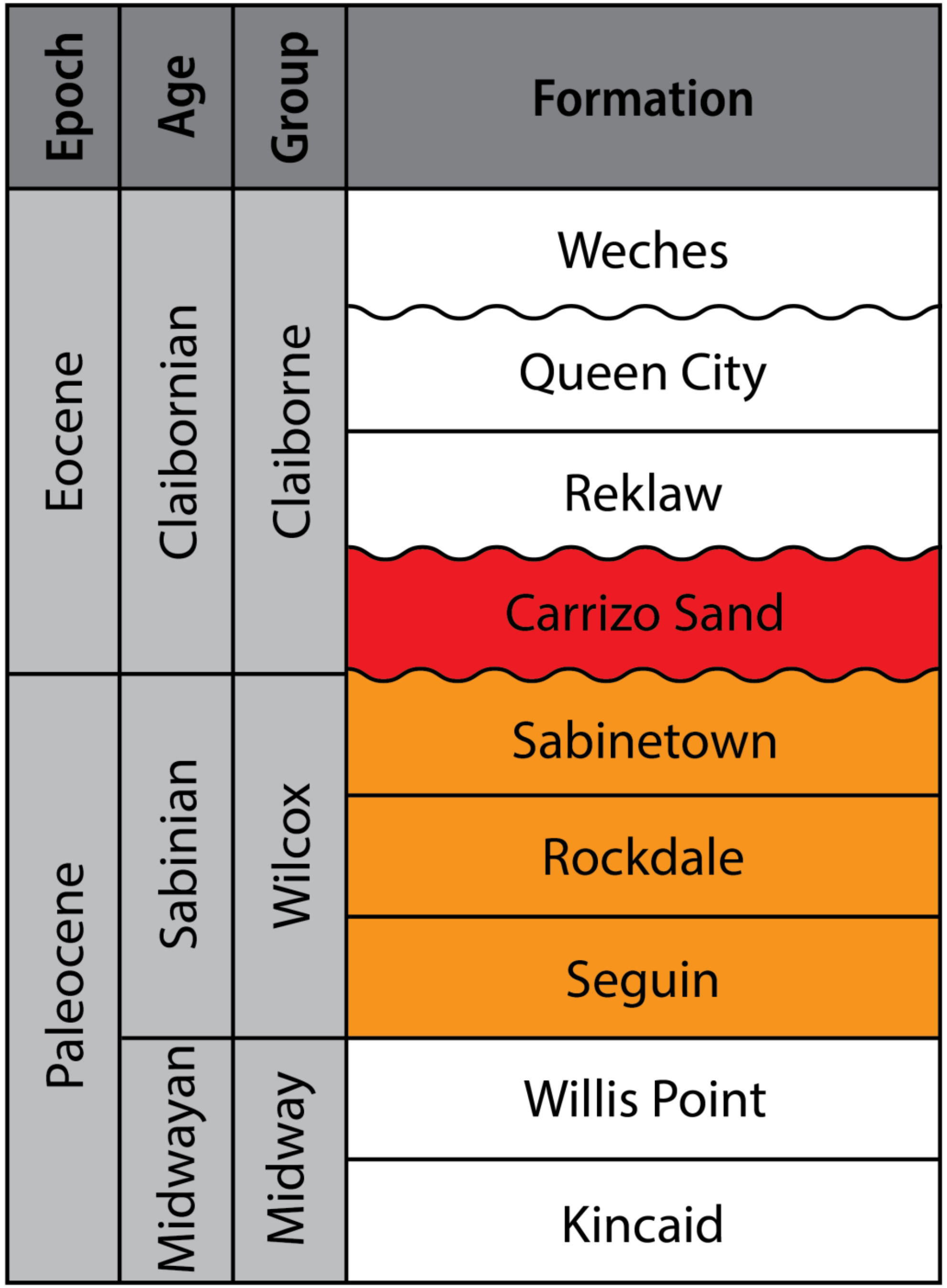


Introduction – study area



- Existing infrastructure
- 2,000-foot depth limit





Stratigraphy

Upper Coastal Plains Aquifer System

- Units trend southwest-northeast, parallel to Gulf Coast
- Units dip southeast and thicken downdip towards the Gulf Coast
- Generally contain gravel, sand, silt, clay, and occasionally lignite

Carrizo Sand

- Unconformably overlies the Wilcox Group
- Contains distinct, thick sandstone units that may contain large-scale crossbedding
- Deposited in a primarily marine shoreface environment as part of a tidal-delta

Wilcox Group

- Consists of alternating units of clay, silt, sand, gravel, and lignite
- Deposited in a range of coastal environments including fluvial, deltaic, and marine
- Study area contains a portion of the Yoakum Canyon

Aquifer characterization

- Stratigraphy
- Lithology
- Groundwater salinity

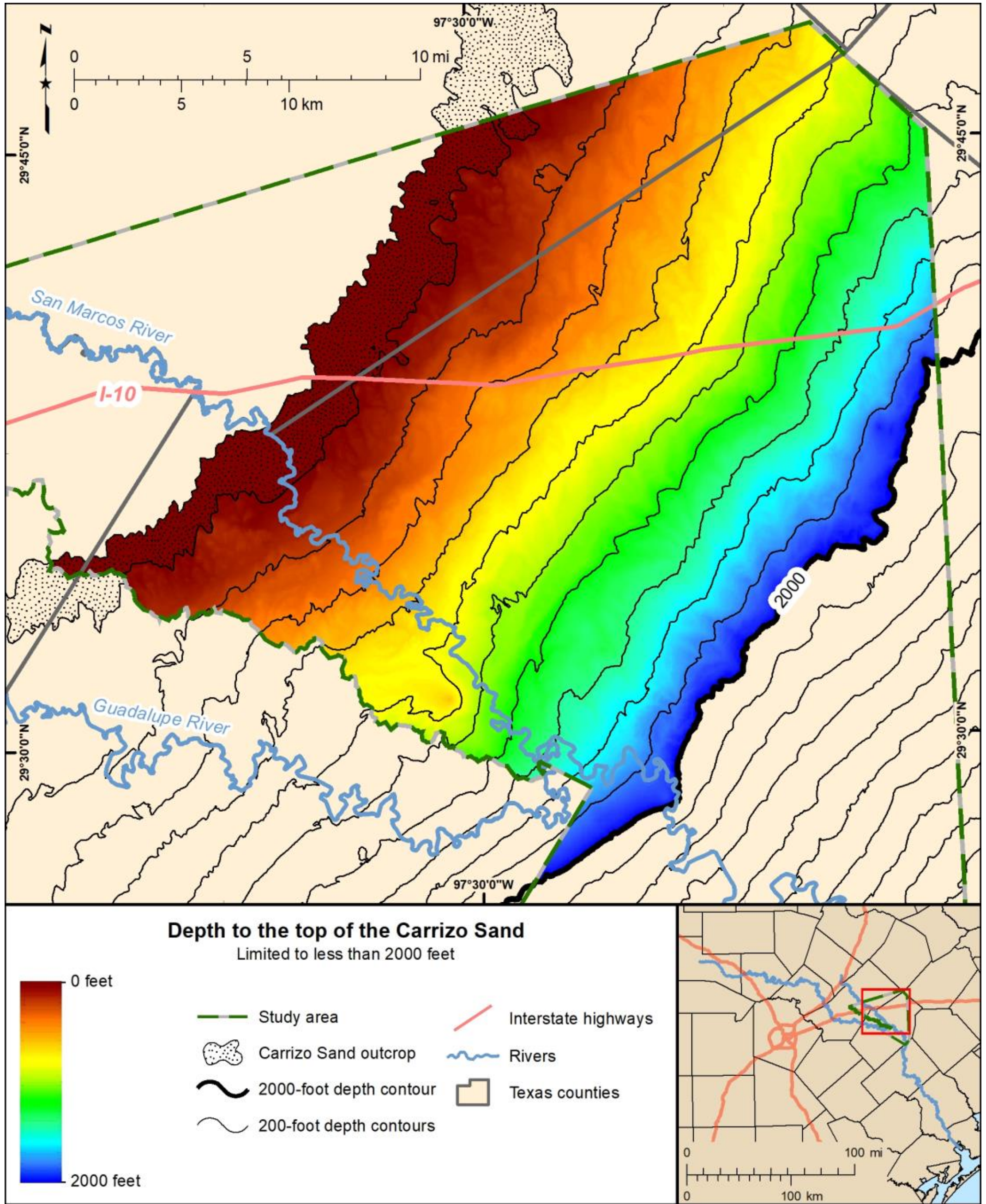
Stratigraphy – why?

- GBRA is planning on implementing ASR in the Carrizo-Wilcox Aquifer
- Determining the depths to the top and bottom of the Carrizo Sand and Wilcox Group will be critical when planning the construction of an ASR well in the study area
- Understanding subsurface architecture will aid in site selection for a viable project

Stratigraphy – how?

- Collect data:
  - Geophysical well logs from the BRACS database
  - Picks from previous studies
  - Added Q-logs from the RRC
  - Added logs from the GBRA CGSP wells
- Additional logs increased the data density from previous studies
- Interpret stratigraphic depths from the well logs in IHS Kingdom
- Interpolate stratigraphic surfaces in ArcGIS

Stratigraphy – results

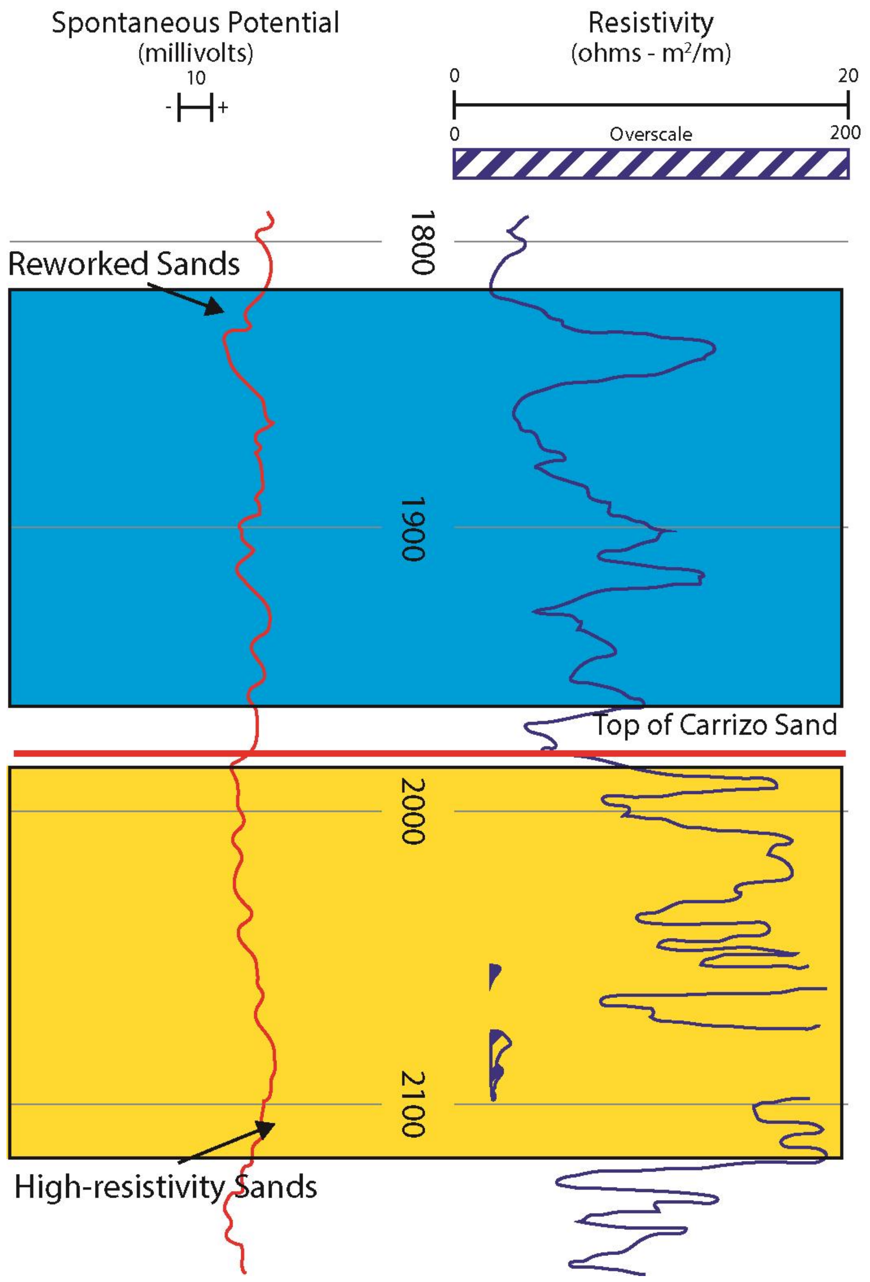


Top of the Carrizo Sand

- Depth increases to the SE, towards the Gulf of Mexico
- The map is limited to where the Carrizo is less than 2,000 feet deep
  - Reaches a depth of 2,000 feet about 15 miles from the outcrop
- 4,547 feet deep at the farthest downdip corner of the study area

Reklaw	Clay, youngest
Carrizo	Aquifer
Wilcox	Aquifer
Midway	Clay, oldest

Stratigraphy – results



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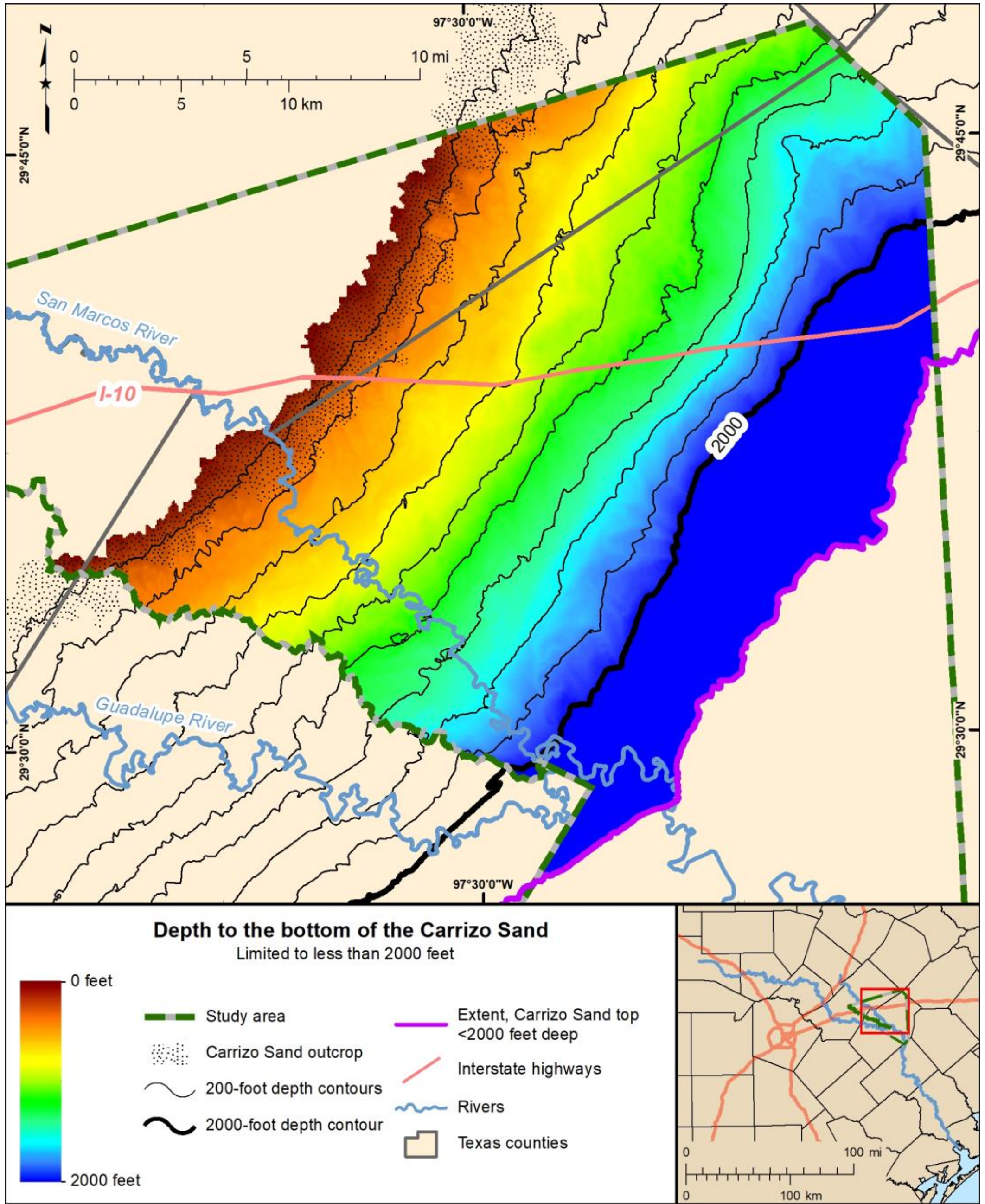
Stratigraphy – results

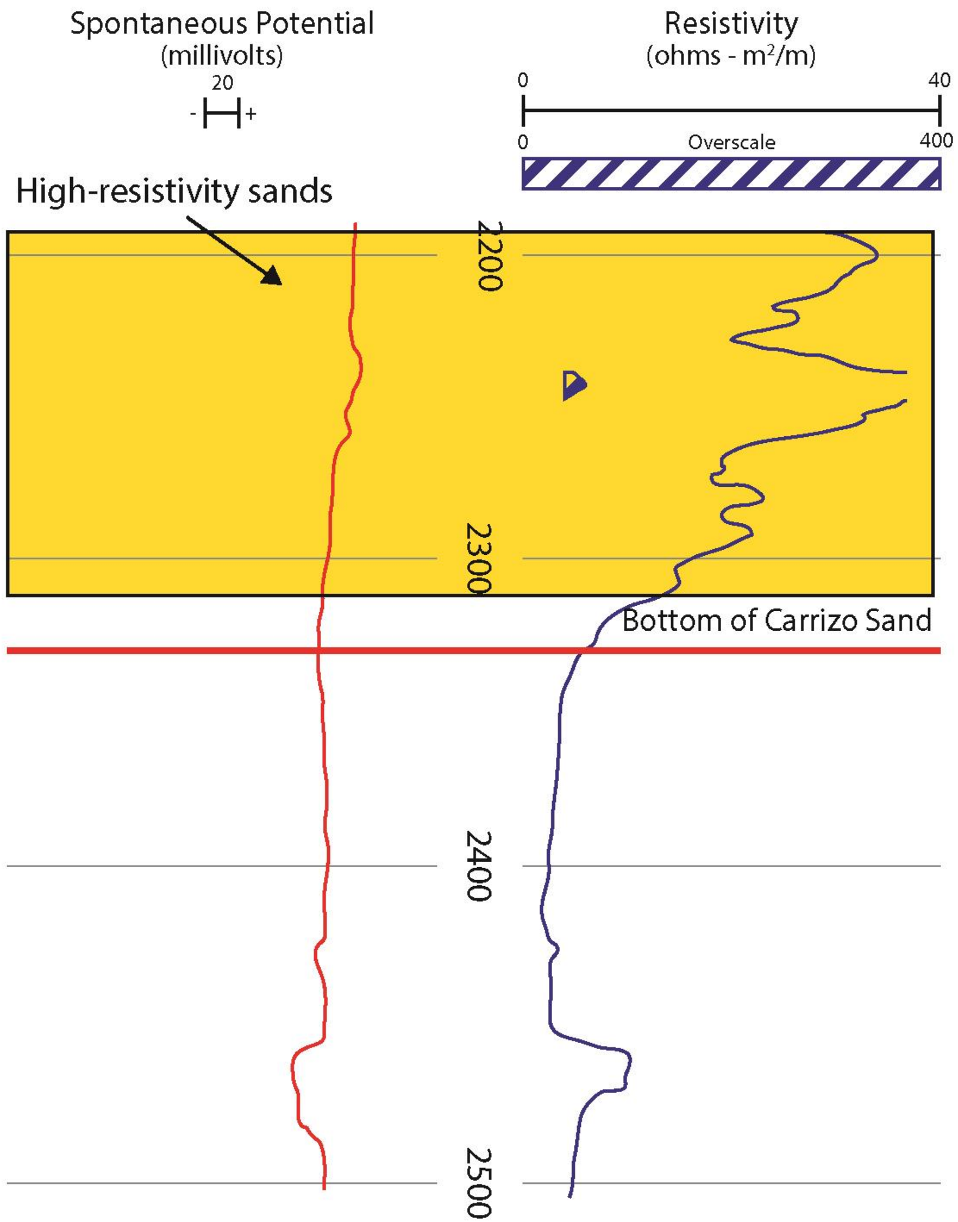


Bottom of the Carrizo Sand (top of the Wilcox Group)

- Depth increases to the SE, towards the Gulf of Mexico
- Reaches a depth of 2,000 feet about 12 miles from the outcrop
- The depth ranges from 0 at the outcrop to 5,517 feet

Reklaw	Clay, youngest
Carrizo	Aquifer
Wilcox	Aquifer
Midway	Clay, oldest

Stratigraphy – results



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Wilcox	Aquifer
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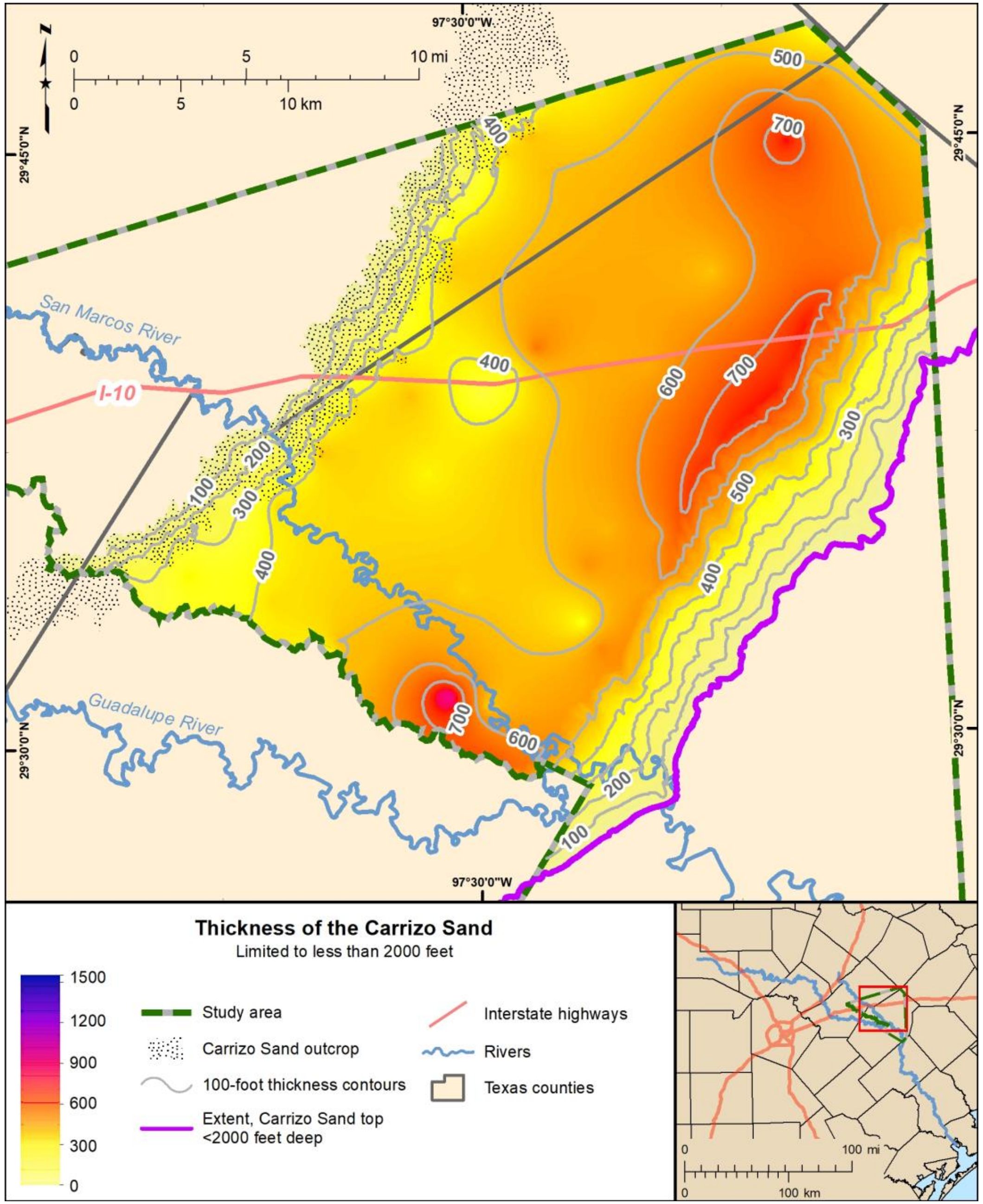
Stratigraphy – results



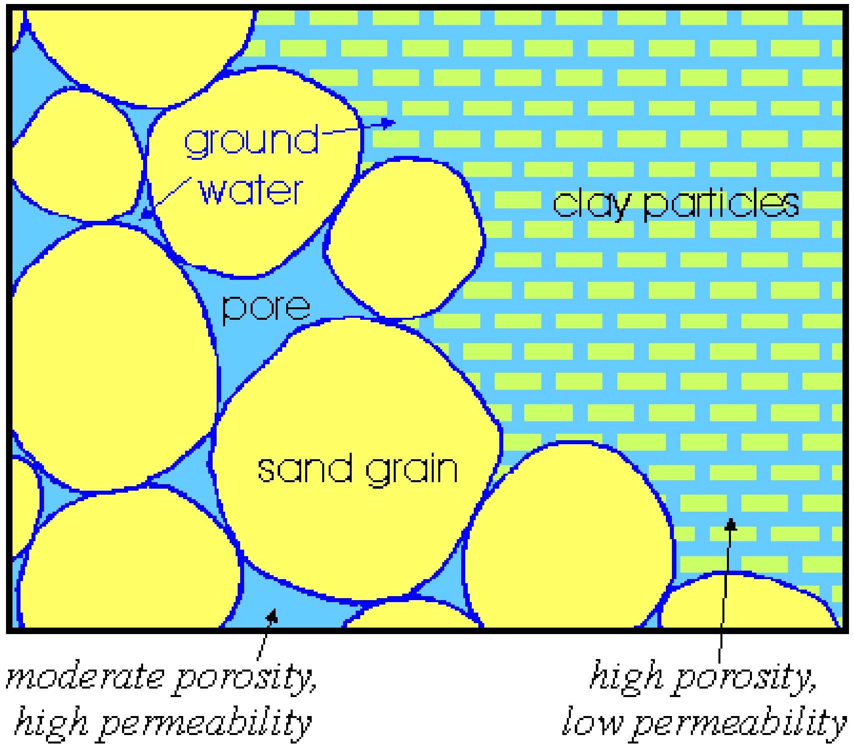
Carrizo Sand thickness

- Map limited to less than 2,000 feet deep:
  - Max thickness is 904 feet
  - Pinches out as the dip of the formation reaches the 2,000 ft depth limit to the SE
- Thickness of the entire formation increases to the SE, towards the Gulf of Mexico
  - Ranges from 0 to 1,173 feet thick
- Thicker where the formation overlies the Yoakum Canyon

Questions on the stratigraphy?

Lithology – why?

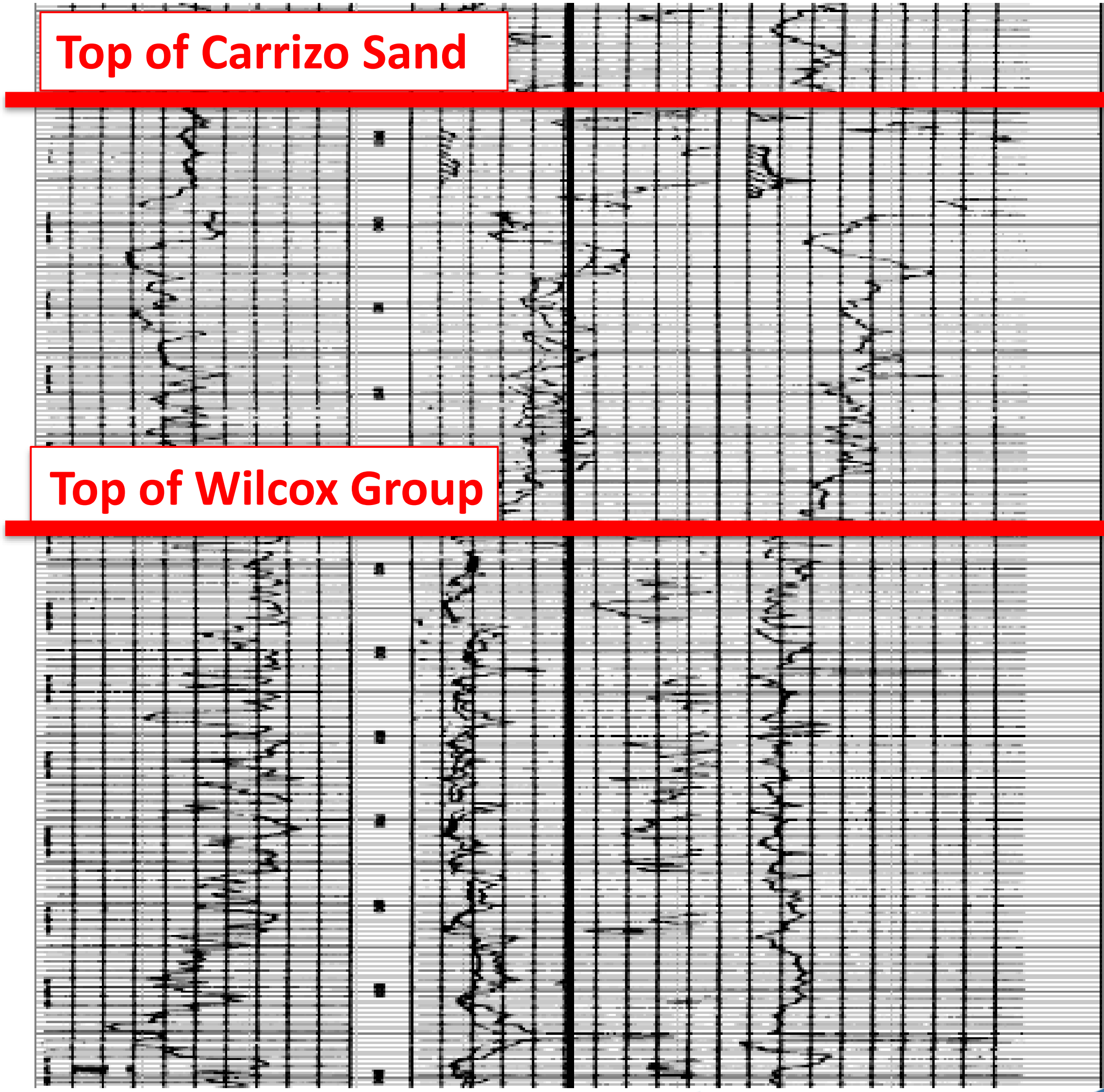
- The dominant lithologic characteristics of strata have a direct effect on the recharge, storage, and recoverability of water
- “Clean” (little to no clay) sand layers produce groundwater more economically and are better suited for ASR projects
- Porosity and permeability of the strata can be inferred from the lithologic characteristics



Lithology – how?

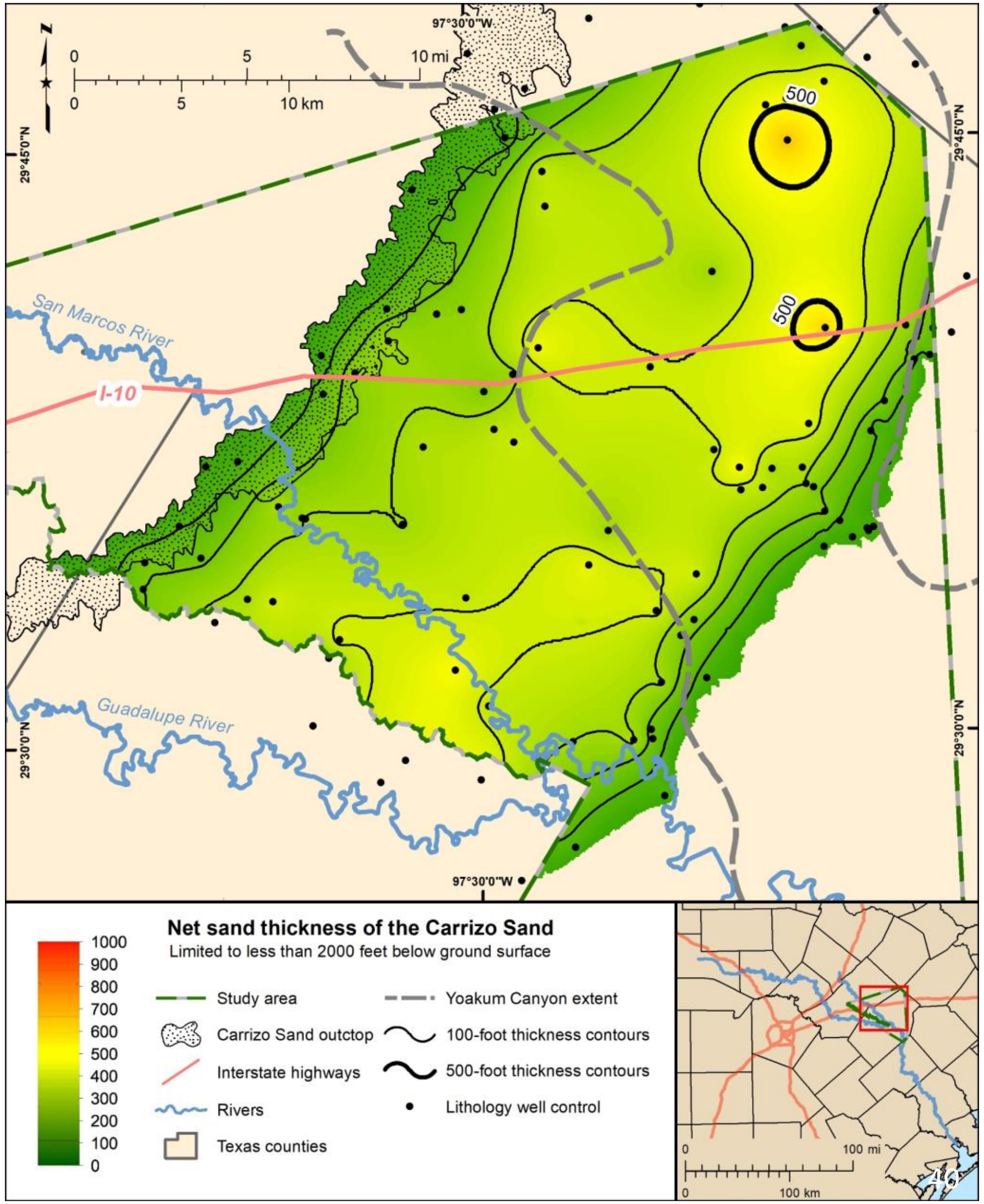
- The Carrizo Sand and Wilcox Group in the study area consist primarily of interbedded sands and clays
- Net sands is the total thickness of sand layers within a given interval
- Net sands may be calculated from driller’s logs or geophysical logs
- Lithology was evaluated using a four-tier method

Tier	Description
Sand	~100% sand
Sand with clay	~75% sand and ~25% clay
Clay with sand	~25% sand and 75% clay
Clay	~100% clay



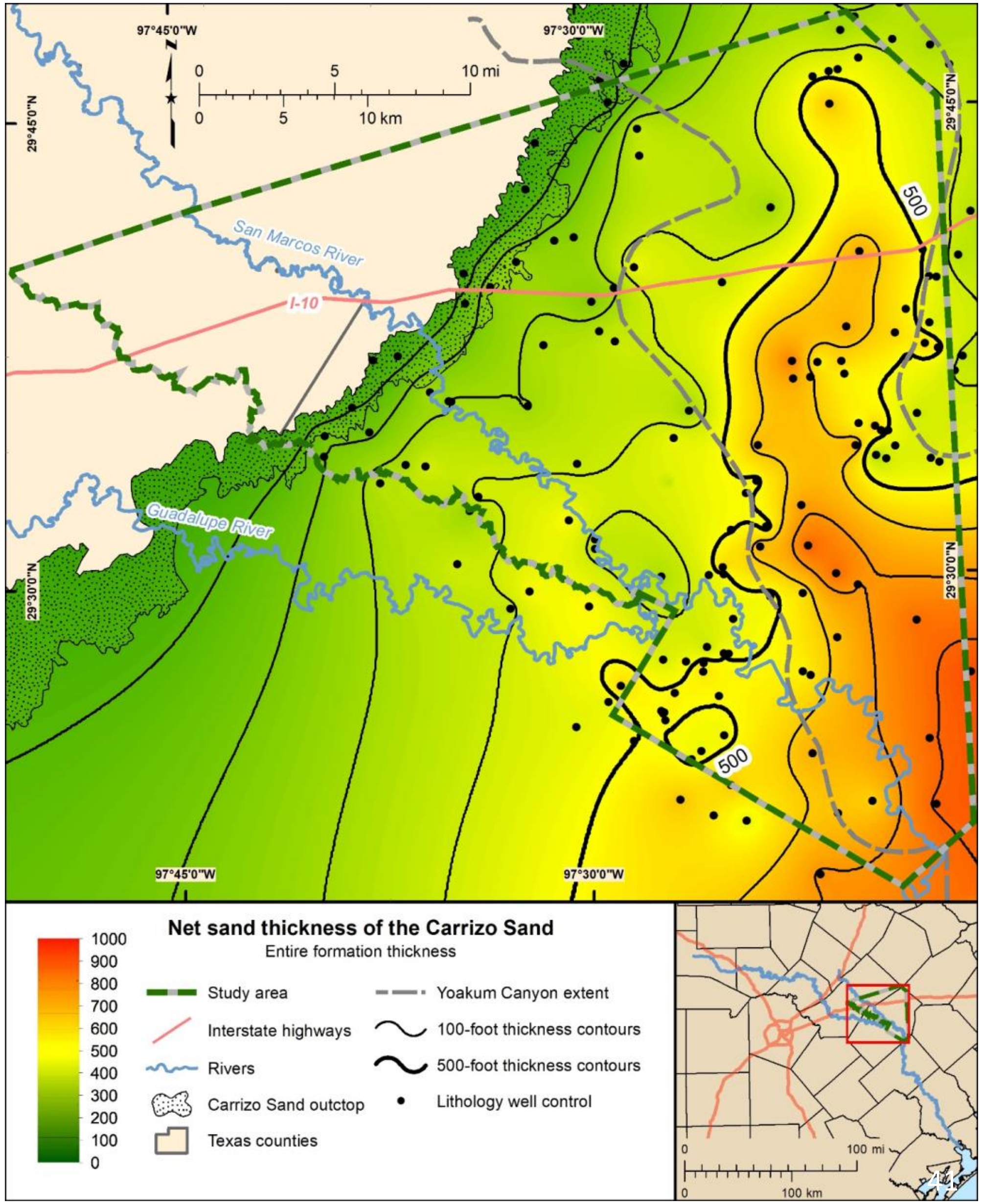
Lithology – results

- **Carrizo Sand**
  - Predominantly quartz sand with some interbedded clays and shales
  - Contains distinct thick, permeable sand units that may be over 500 feet thick
  - Deposited in a marine environment
  - 100 logs were used for interpretation
  - Between the surface and 2,000 feet below ground level there are up to 623 feet of net sands
  - Thickest net sands overlie the Yoakum Canyon



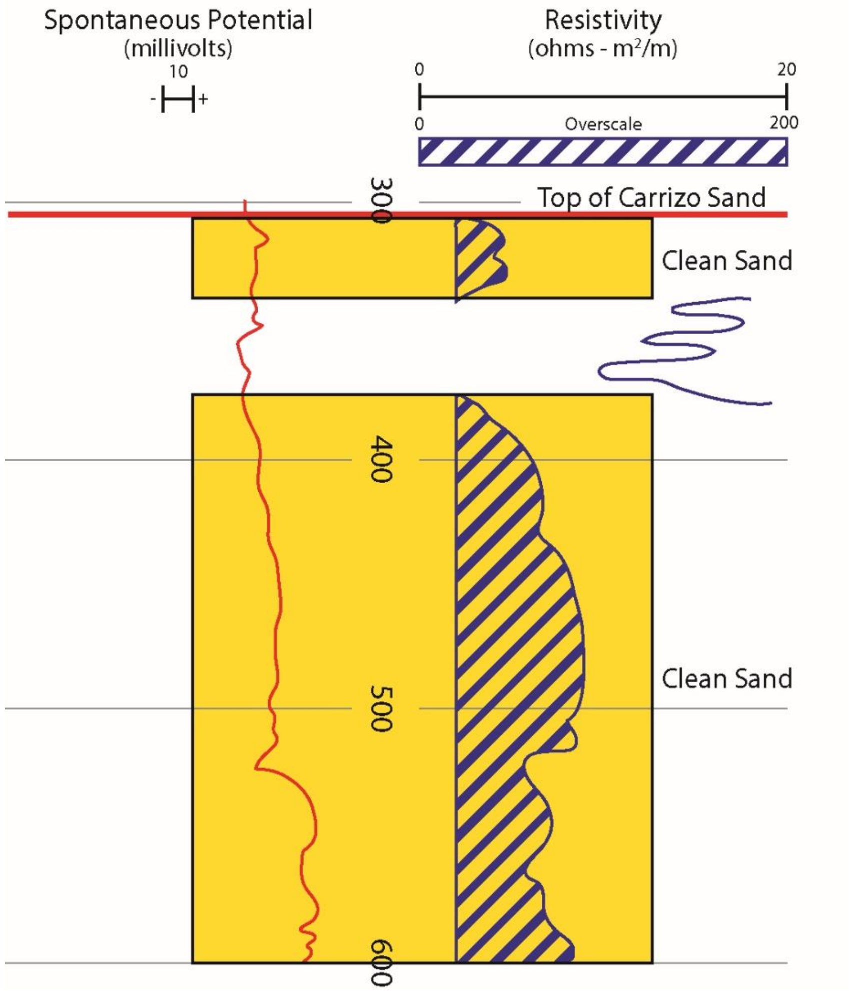
Lithology – results

- **Yoakum Canyon**
  - Located within the Wilcox Group
  - Can be followed for 67 miles from outcrop through the subsurface
  - Cut into the Wilcox Group during deposition and refilled
  - Primarily shale with some isolated sand beds near top of unit
- **Carrizo Sand that overlies the Yoakum canyon is distinct from the surrounding strata**
  - Generally thicker with more overall net sands
  - Individual sand units are thinner and vertically isolated
  - Permeability is generally lower (lower resistivity)

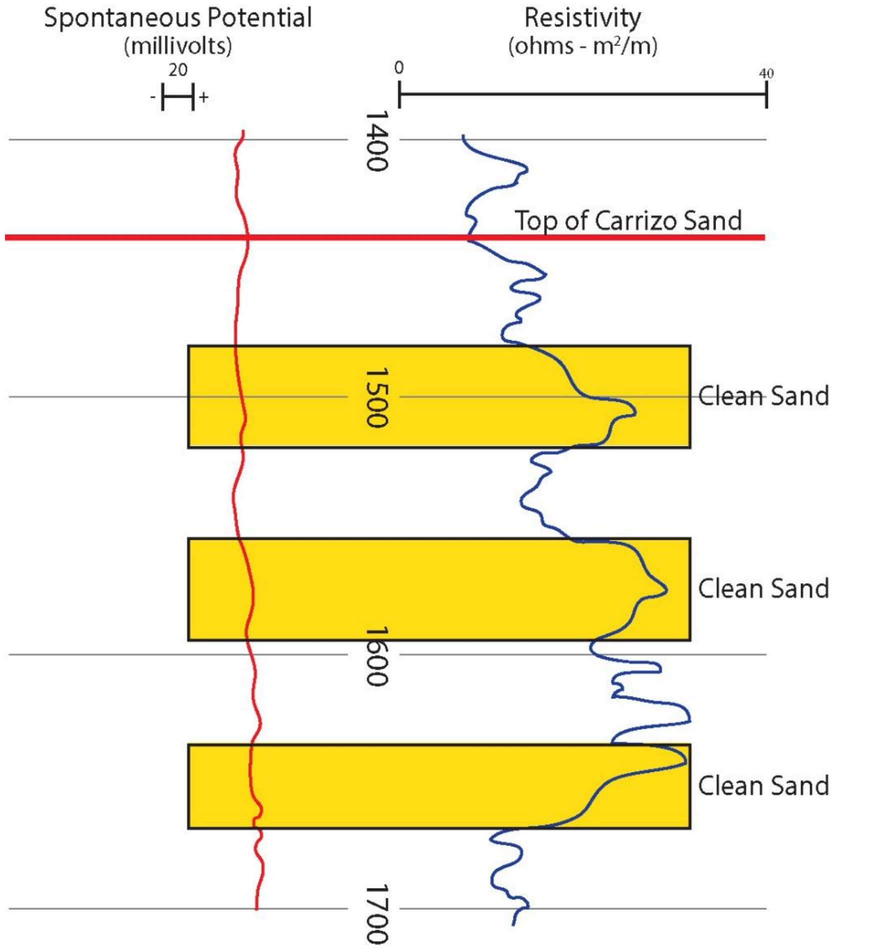


Lithology – results

Typical Carrizo Sand in the study area



Carrizo Sand overlying the Yoakum Canyon



Questions on the lithology?

Groundwater salinity – why?

- Water quality of the native groundwater is an important hydrogeological characteristic for ASR
- Salinity is an important water quality parameter and has implications for an ASR project:
  - designing a well
  - planning operations and establishing a buffer volume
  - water treatment requirements

Groundwater salinity – how?

- Collected total dissolved solids (TDS) values from available measured water quality data
  - Most measured water quality samples come from water wells
- Measured water quality is not available in downdip area of the aquifer, so TDS was calculated from geophysical well logs
  - Values were calculated using the relationships between TDS, specific conductance, and formation resistivity
- Salinity class maps were created using both measured and calculated TDS values

What are salinity classes?

Groundwater Salinity Classification	Salinity Zone Code	Total Dissolved Solids Concentration (milligrams per liter)
Fresh	FR	0 to 1,000
Slightly Saline	SS	1,000 to 3,000
Moderately Saline	MS	3,000 to 10,000
Very Saline	VS	10,000 to 35,000
Brine	BR	Greater than 35,000

modified from Winslow and Kister (1956) USGS WSP 1365

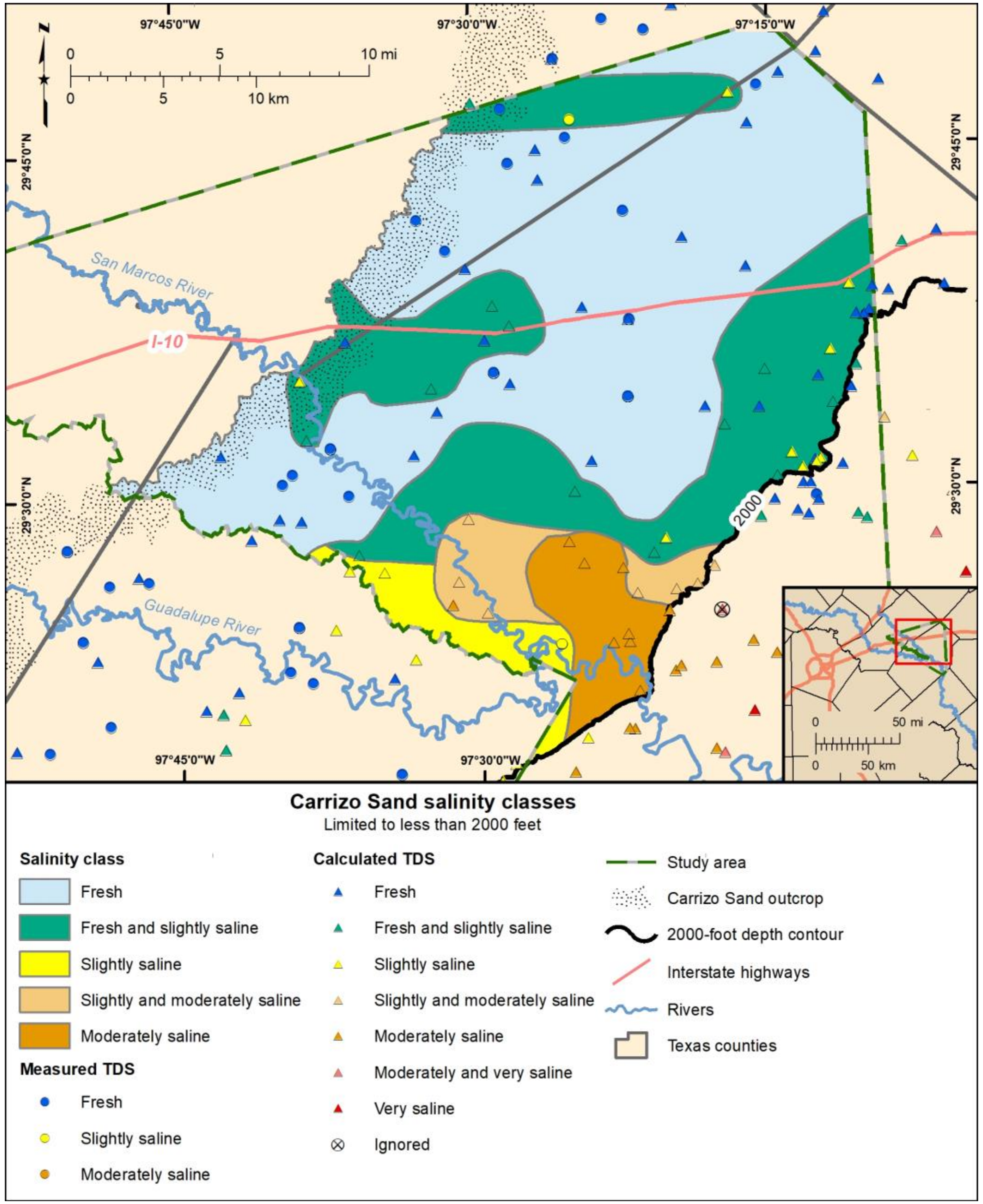
Brackish

Current desalination sources

Seawater

Most produced water

Groundwater salinity – results



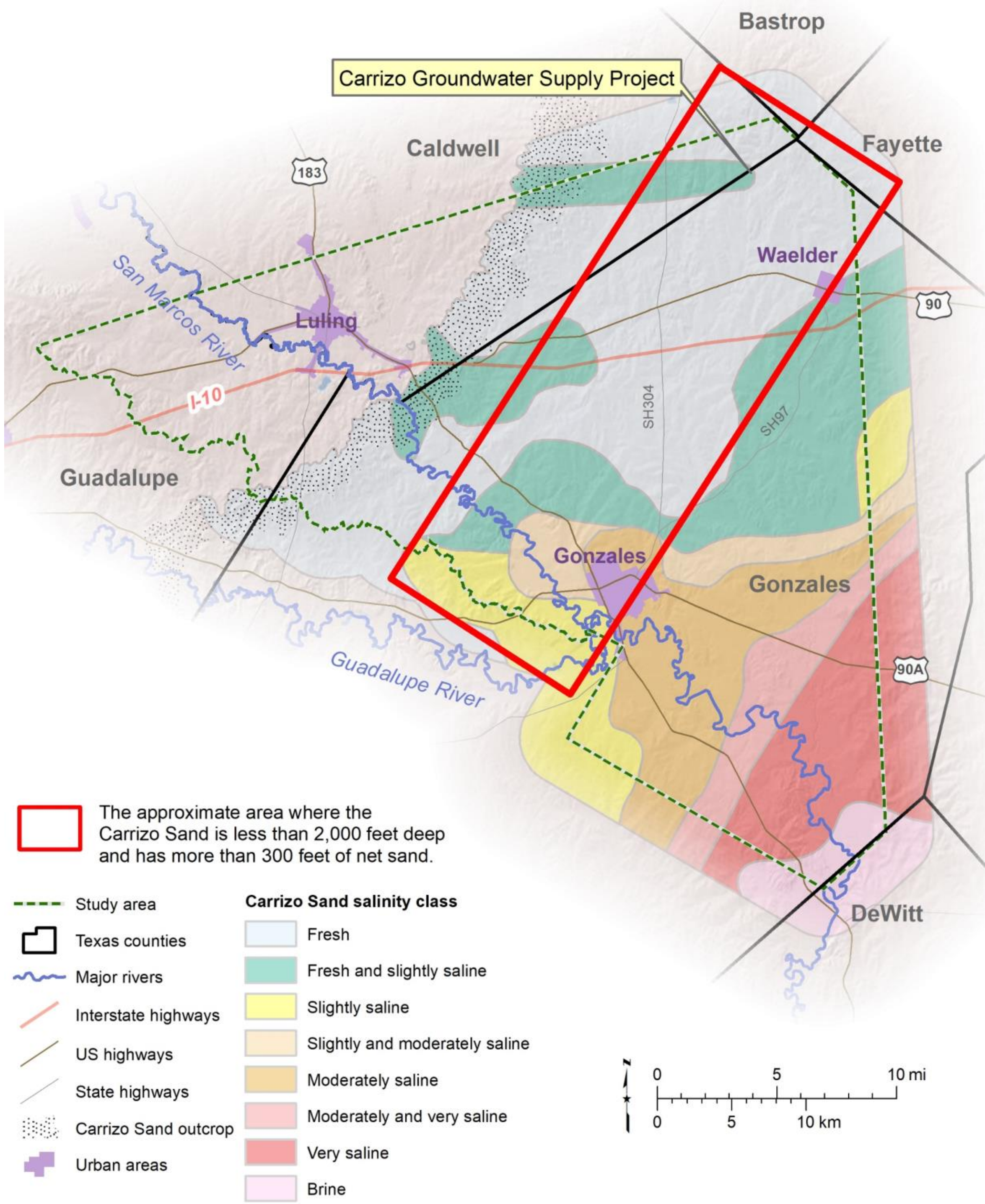
Carrizo Sand

- 20 wells with 80 measured water quality samples
  - 7 fresh samples, 72 slightly saline samples, and 1 moderately saline sample
- 123 well logs for TDS calculations
- 164 salinity class intervals were assigned:
  - 63 fresh
  - 56 slightly saline
  - 35 moderately saline
  - 8 very saline
  - 2 brine
- Analysis was limited to 2,000 feet below ground surface

Questions on the groundwater salinity?

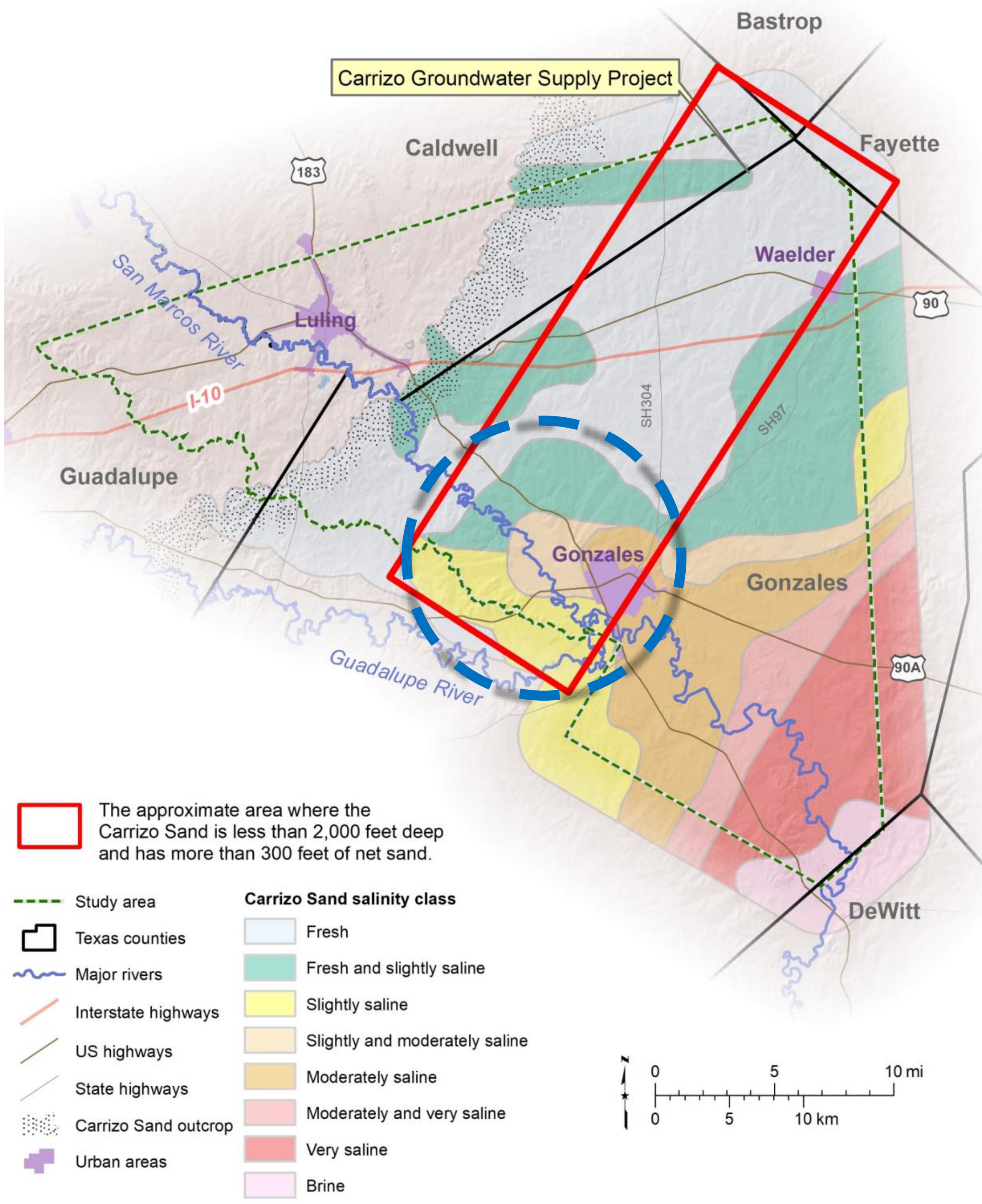
Discussion – site selection considerations

- Carrizo Sand is the better candidate for ASR based on stratigraphy, lithology, and water quality
- The middle third of the study area, Carrizo Sand contains ≥300ft of net sand <2,000ft below the ground surface
- Wells deeper than 2,500 ft would require costly multi-stage pumping
- The SAWS ASR project screens ~250ft of the Carrizo Sand



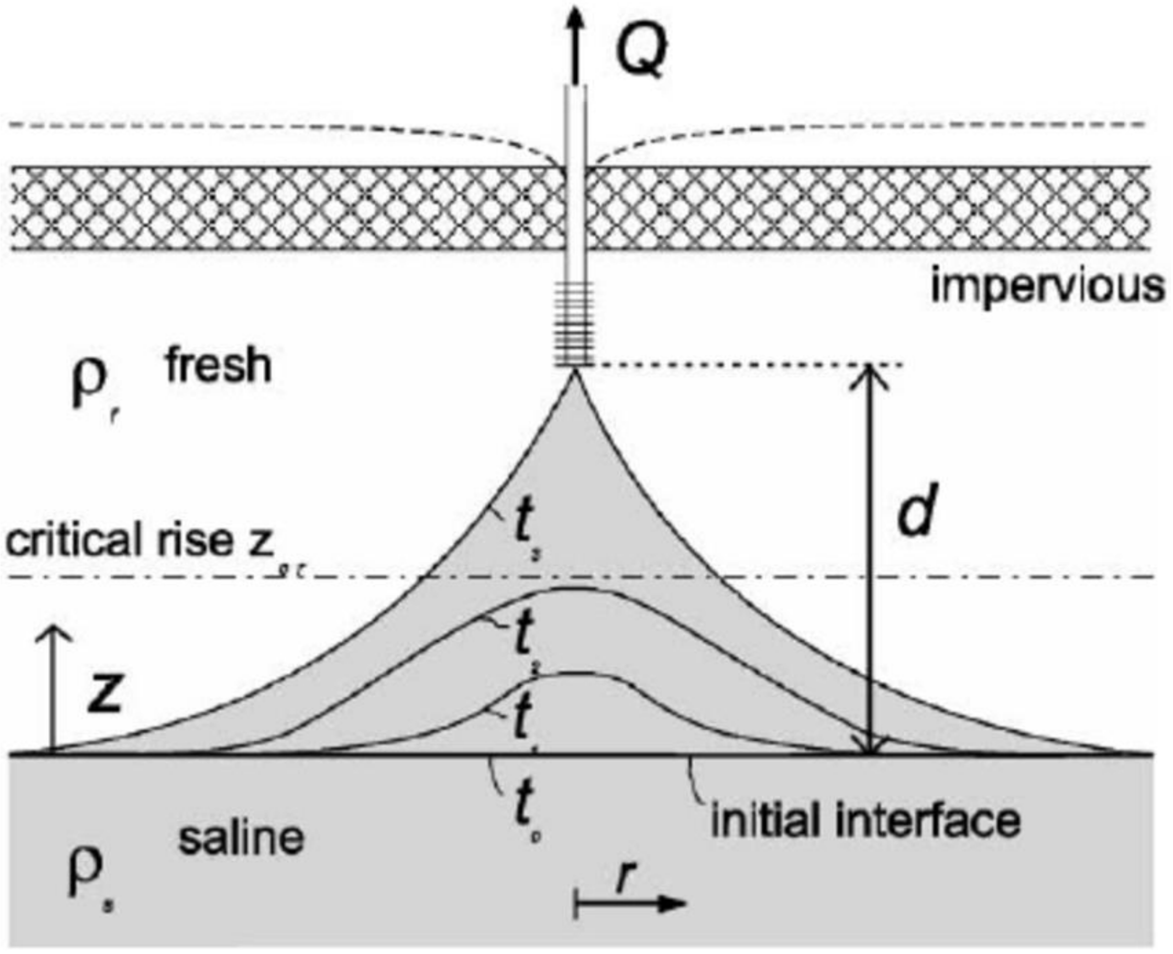
Discussion – site selection considerations

- Zone of higher salinity near the City of Gonzales
- This higher salinity zone is close to the Guadalupe River, which is the source water for the project
- Site section will need to take all these considerations into account along with current and future regional infrastructure



Discussion – well construction

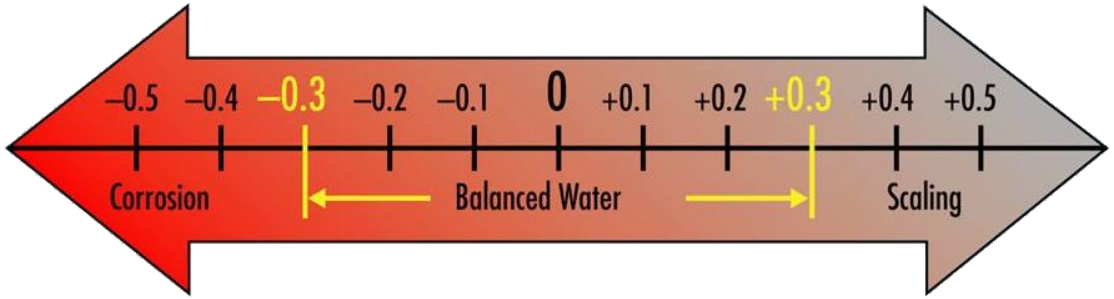
- Water quality (injected and native) has implications on well design, construction, and operations
  - Interbedded clays may lead to lower water quality
  - More saline environments will require more water loss to establish a buffer
  - The units contain many stacked salinity zones so potential drawup of more saline water may be a concern



From Essink (2001)

Discussion – well construction

- Chemical compatibility
  - Corrosive of encrusting groundwater conditions
  - Langelier Saturation Index (LSI) –shows whether water will be encrusting (positive) or corrosive (negative)
- Carrizo Groundwater Supply Project (Phase I) wells 1-3 have an LSI from -2.30 to -2.55 (corrosive) so plan casing material accordingly



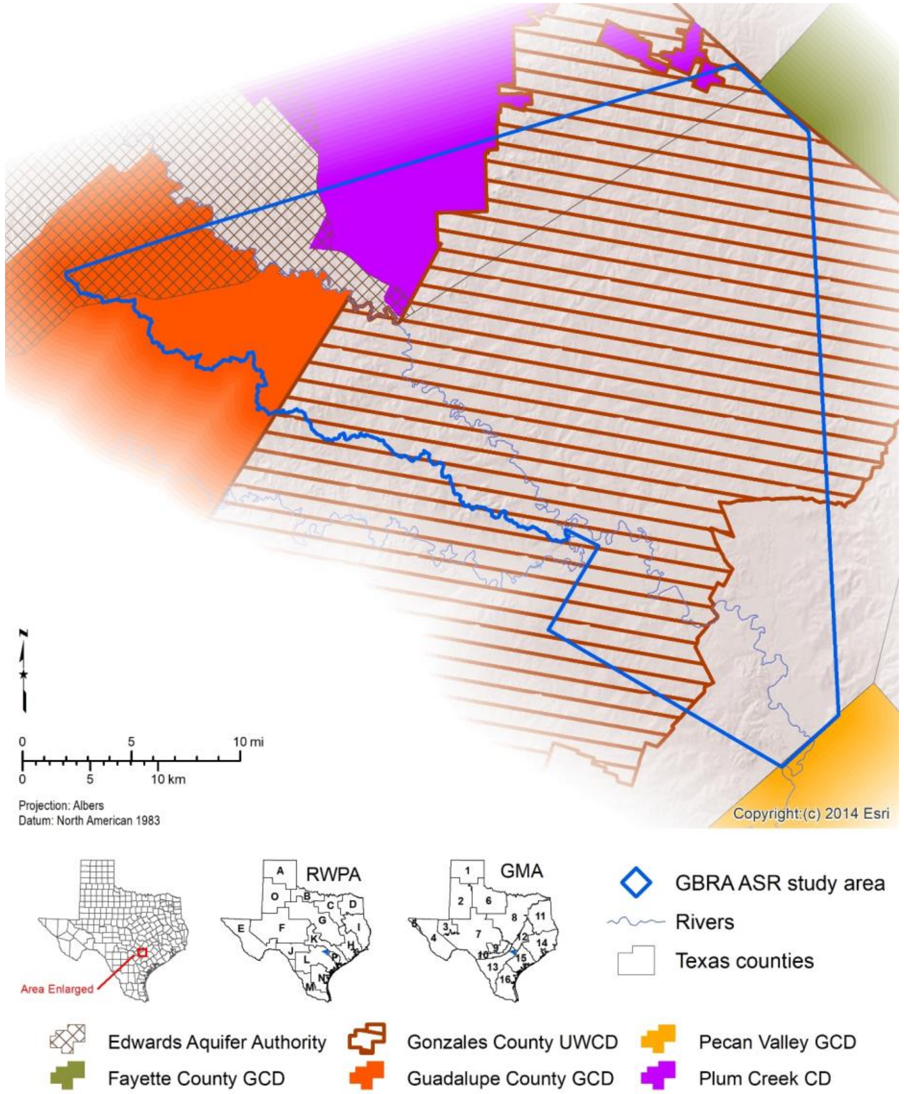
$$LSI = pH + \log\left(\frac{K_a \cdot \gamma_{Ca^{2+}} \cdot [Ca^{2+}] \cdot \gamma_{HCO_3^-} \cdot [HCO_3^-]}{\gamma_{H^+} \cdot K_{sp}}\right)$$

Discussion – limitations

- Aquifer characteristics are only one component of site selection and future work may include
  - Engaging potential stakeholders;
  - Evaluating existing and planned infrastructure;
  - Estimating total project costs;
  - Investigating environmental impacts; and
  - Calculating economic viability.
- Collection of well-field scale data on water quality and hydrogeology is recommended to evaluate a final site location for an ASR field and associated system.

Discussion – regulation and permitting

- Implementation of ASR projects is regulated by the Texas Commission on Environmental Quality (TCEQ) Underground Injection Control Program
- ASR wells permitted as Class V injection wells
- Full regulatory requirements are in 30 Texas Administrative Code § 331

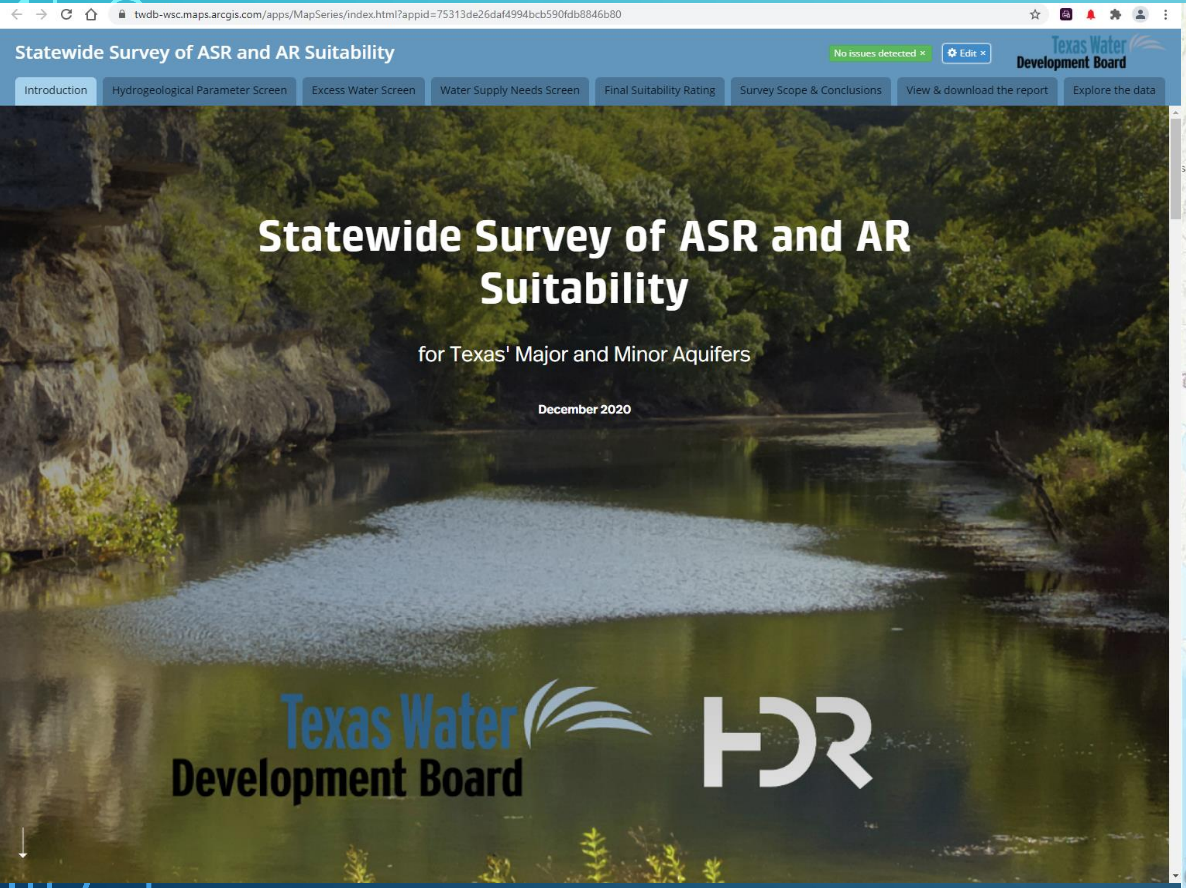


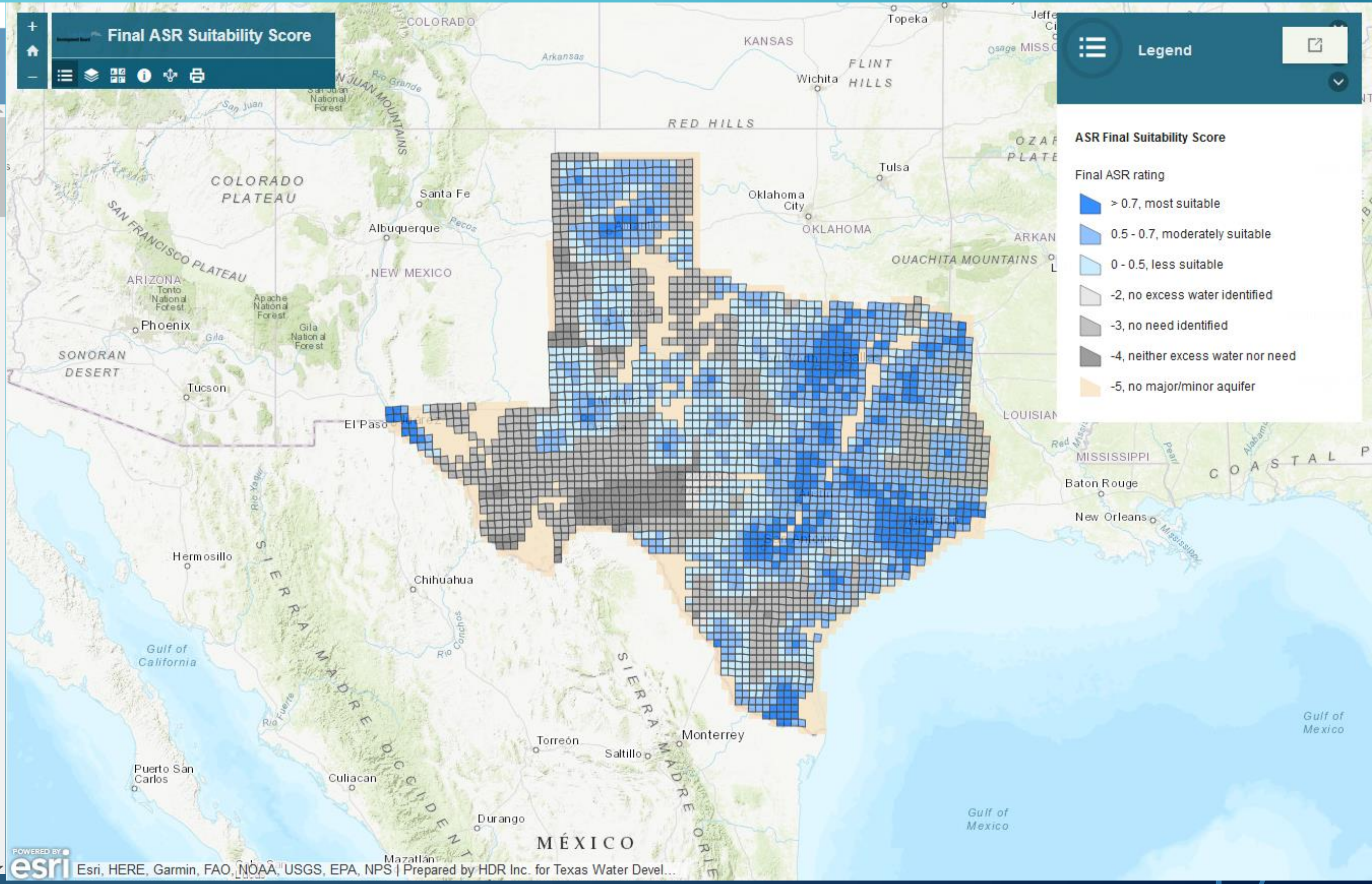
Conclusions

- Publicly available aquifer characteristics of the Carrizo-Wilcox Aquifer for site selection
- ~568 sq. mi. study area, data from 662 wells
- Variability in sand and water quality distribution
- Most favorable hydrogeological characteristics found in a 9 x 25 mi. swath of Carrizo Sand
- Water quality should be considered in well design

Questions on the discussion and conclusions sections?

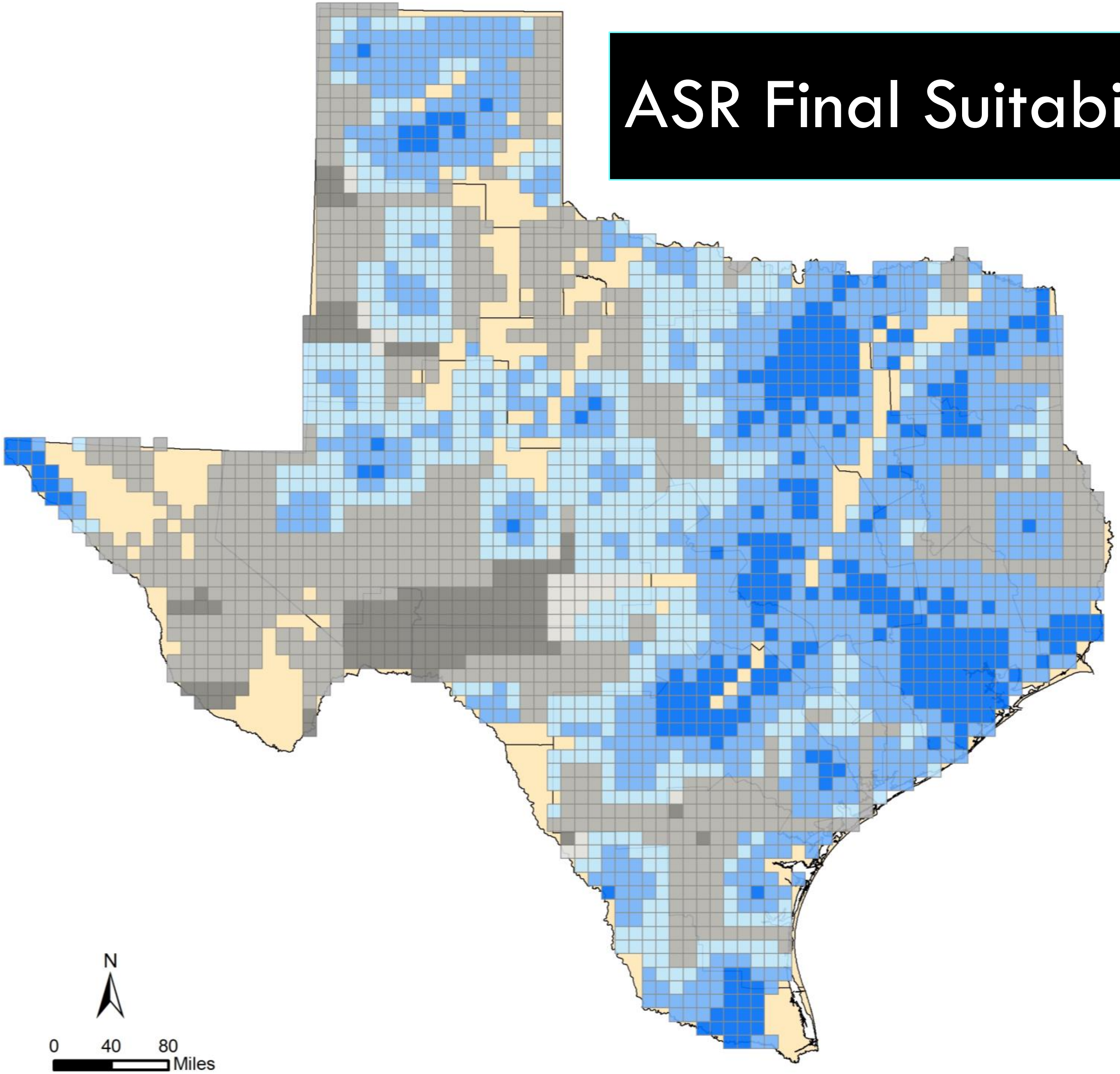
Statewide Suitability Survey for ASR or AR (2020)

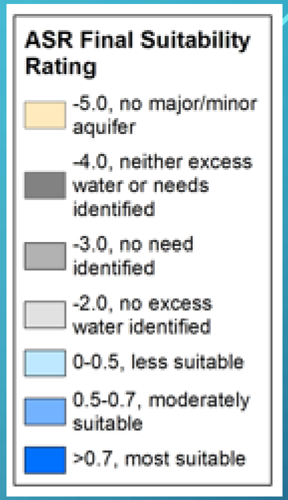


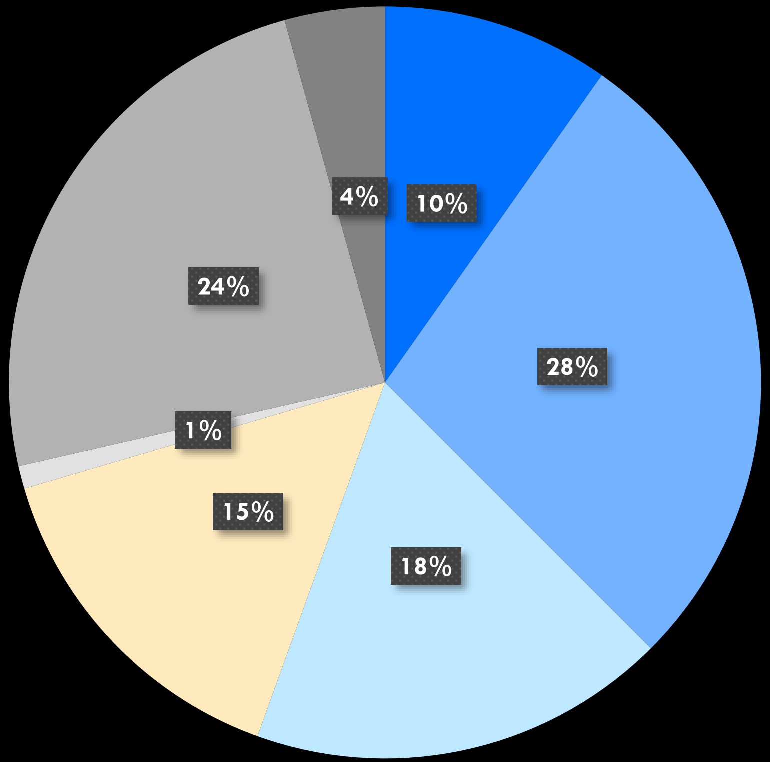


https://twdb-wsc.maps.arcgis.com/apps/MapSeries/index.html?appid=75313de26daf4994bcb590fdb8846b80

ASR Final Suitability Rating







Benefits and Uses

- **Benefits**

- Free and public
- Data accessibility
- Data versatility
- Dovetails with the water planning process

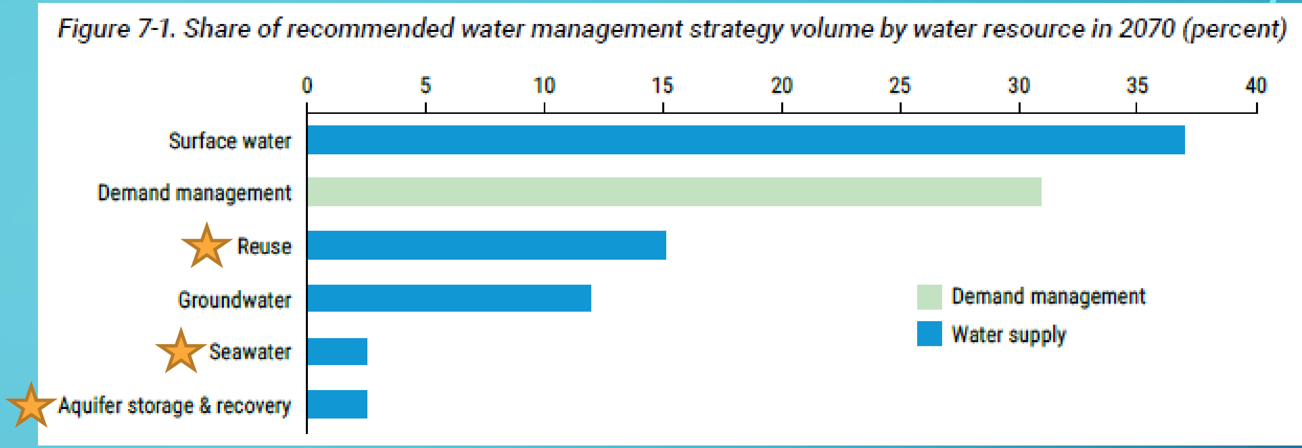
- **Uses**

- Start conversations
- Explore the data
- Identify areas that could warrant a feasibility analysis
- Arrive at your own conclusions

Project web page:

Story map:

CLOSING THOUGHTS



- Innovative water technologies are the future water supplies of Texas
- Do not forget public outreach
- Acceptable risk v. no action scenario

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www.twdb.texas.gov/innovativewater/index.asp

What is now proved,

was once only imagined.

-William Blake