ARCADIS Design & Consultancy for natural and built assets

AQUIFER STORAGE AND RECOVERY

BASIC ELEMENTS FOR WATER SUPPLY MANAGEMENT

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Vice President, Principal-in-Charge

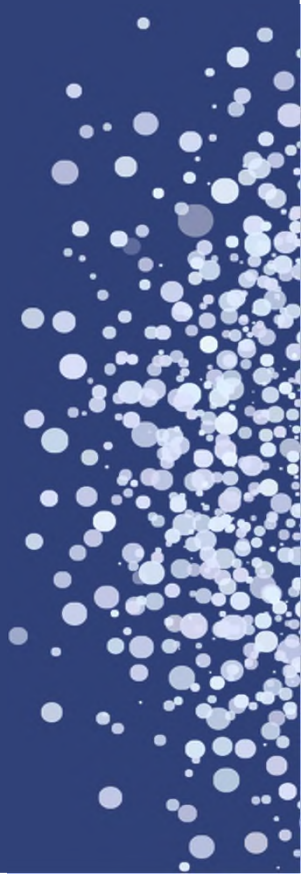
Arcadis

November 9, 2021

Outline

- Background:
  - ASR
  - NBU
- Site Selection
- Site Characterization
- Physical & Geochemical Attributes
- Construction
- Q&A

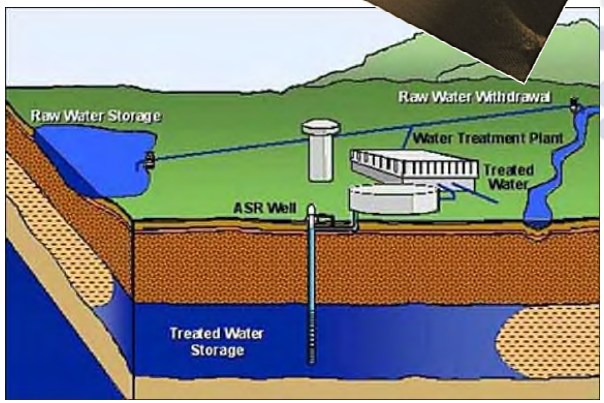
A Good Foundation Is Important



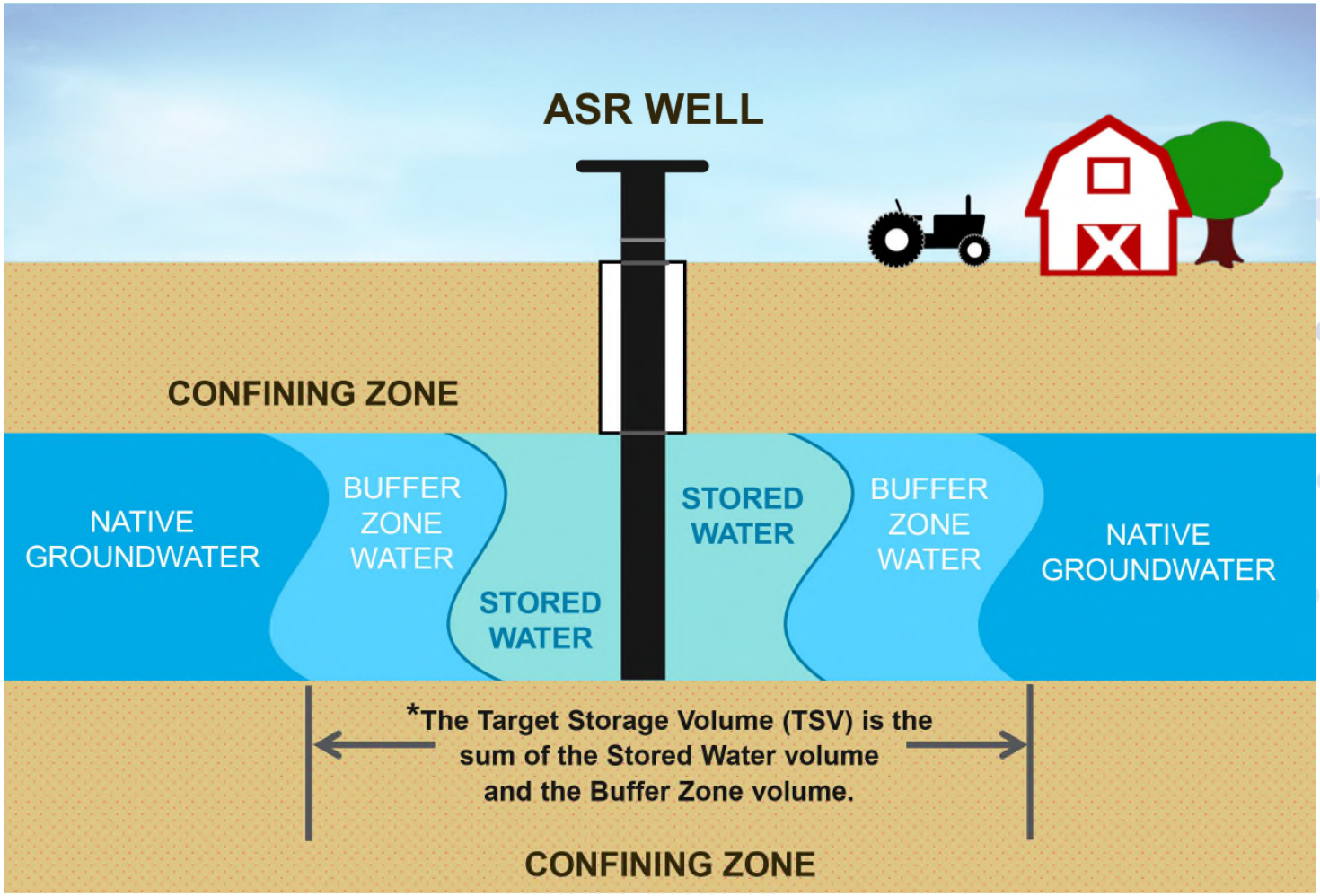
Aquifer Storage & Recovery (ASR) is:

"…the storage of water in a suitable aquifer … during times when water is available, and recovery of that water … during times when it is needed."

David Pyne, P.E.
ASR Systems, LLC
Gainesville, FL

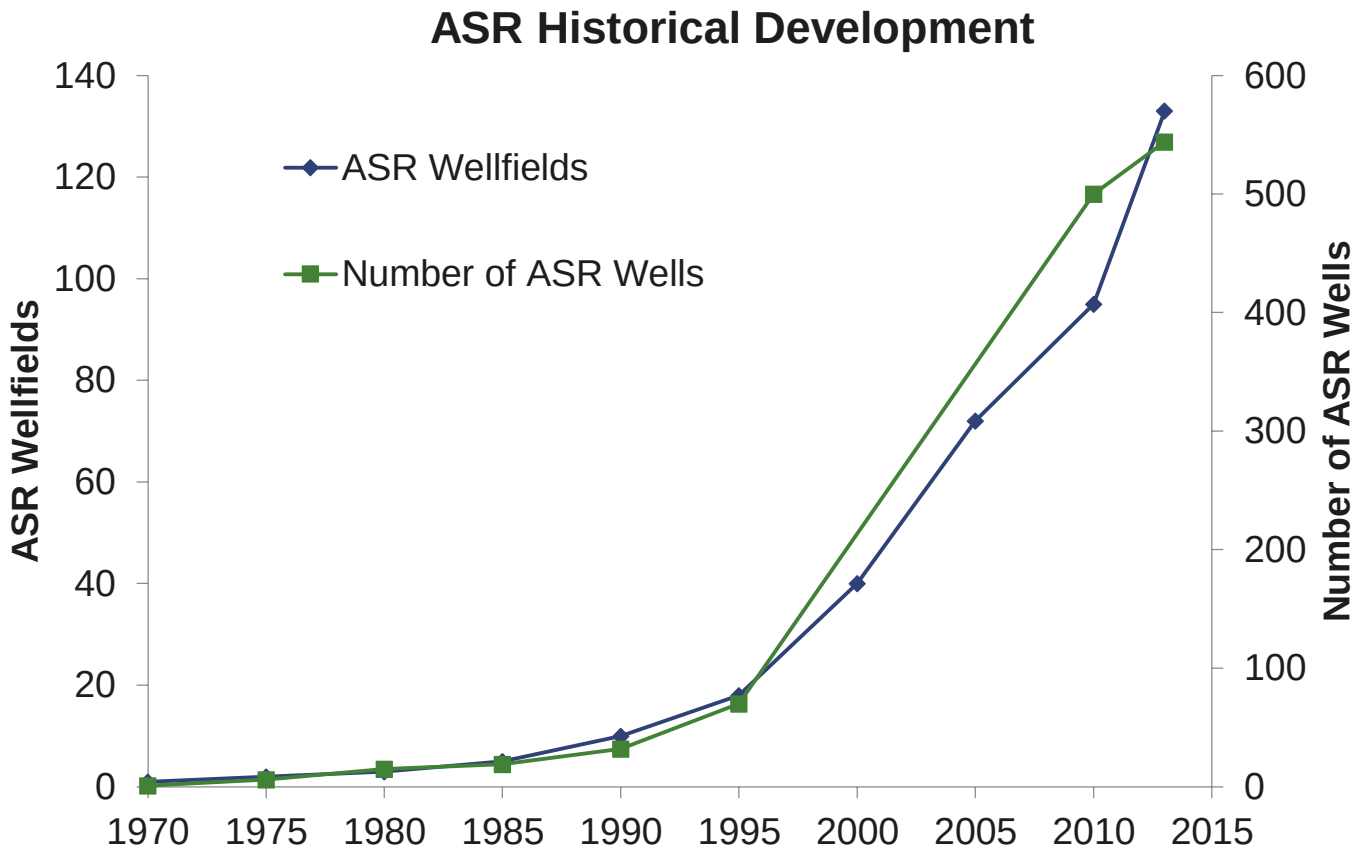


ASR Concept and Terminology



ASR Development in the U.S.

Over 500 ASR wells in 133 ASR wellfields in 21 states



Source: ASR Systems, LLC

ASR Applications

- Seasonal storage and peaking
- Long term storage for water supply
- Emergency supply
- DBP reduction
- Deferral of water facility expansions
- Maintenance of distribution system pressure/ flow
- Improvement of water quality
- Prevention of saltwater intrusion

Approximately 15 other applications worldwide

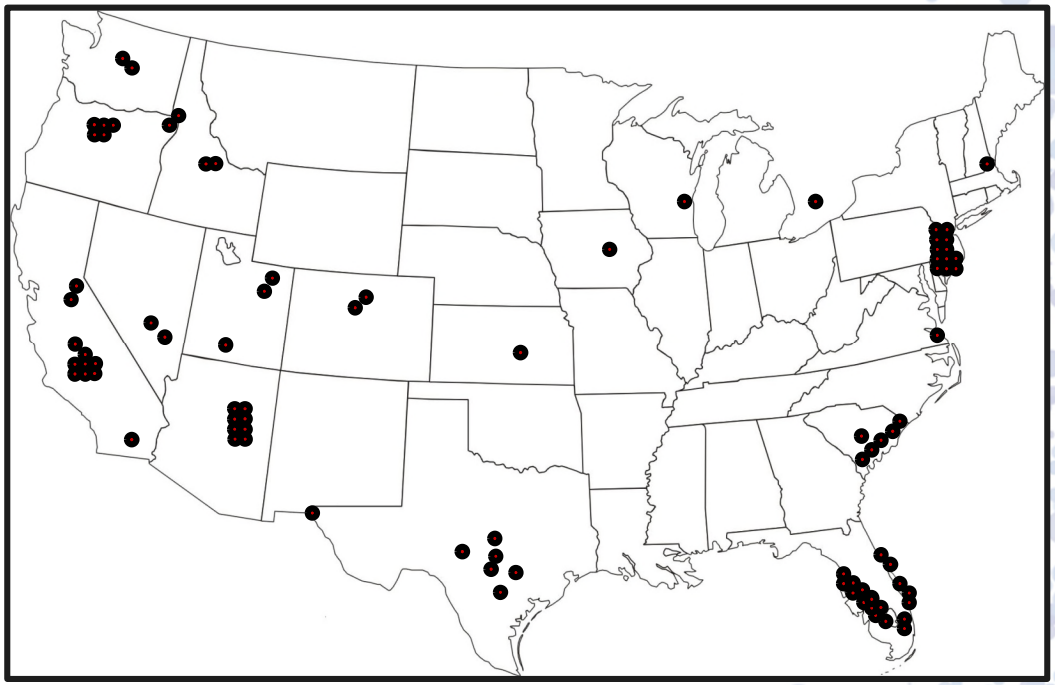
ASR Development in Texas

Three in operation:

- El Paso
- San Antonio
- Kerrville

Others in development:

- City of Victoria
- New Braunfels Utilities
- Guadalupe Blanco River Authority
- Buda



ASR in Texas: El Paso Water

First “ASR” project in Texas

System Components	• 4 injection wells • 6 spreading basins
Capacity	Approx. 10 MGD
Source	Treated wastewater from Fred Hervey WRP
Storage Zone	Hueco Bolson Aquifer
Primary Application	Recharge aquifer and reverse decline

ASR in Texas: SAWS

Second-largest in the U.S.

System Components	• 29 ASR wells • 7 production wells • 15 monitoring wells
Capacity	60 MGD
Source	Edwards Aquifer
Storage Zone	Carrizo Wilcox Aquifer
Primary Application	Sustainable supply during normal drought cycles

ASR in Texas: SAWS

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System Components	• 29 ASR wells • 7 production wells • 15 monitoring wells
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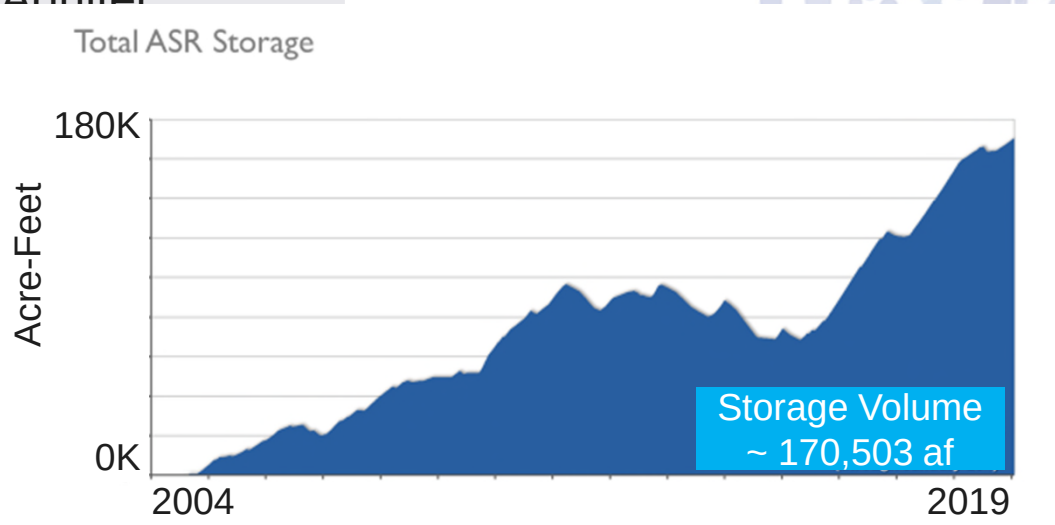

Source: San Antonio Water System

ASR in Texas: City of Kerrville

2nd ASR project in Texas (1995)

System Components	2 ASR wells (third in development)
Capacity	2.65 MGD
Source	Treated surface water from Guadalupe River
Storage Zone	Lower Trinity Aquifer
Primary Application	• Storage for drought • Meeting peak demand • Emergency needs

ASR in Texas: City of Kerrville

2nd ASR project in Texas (1995)

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Capacity	2.65 MGD
Source	Treated surface water from Guadalupe River
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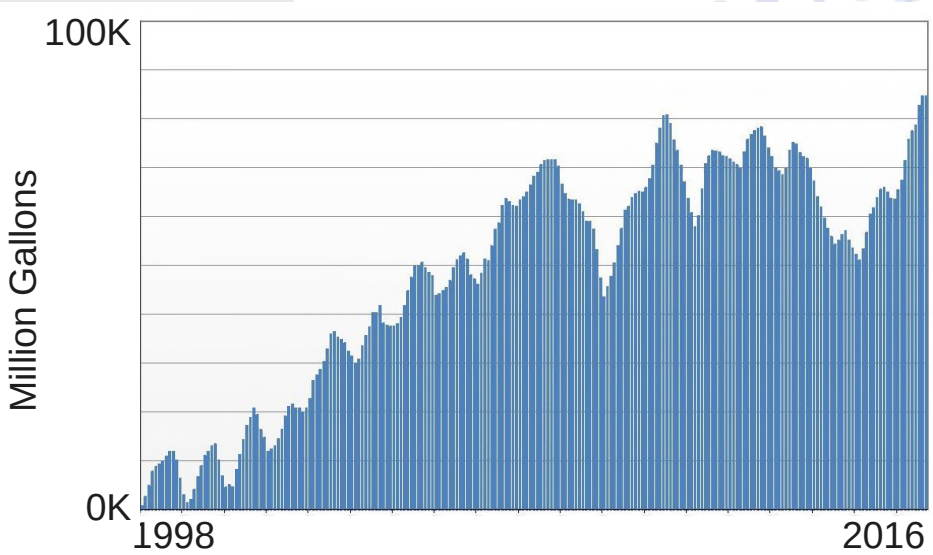


Source: City of Kerrville

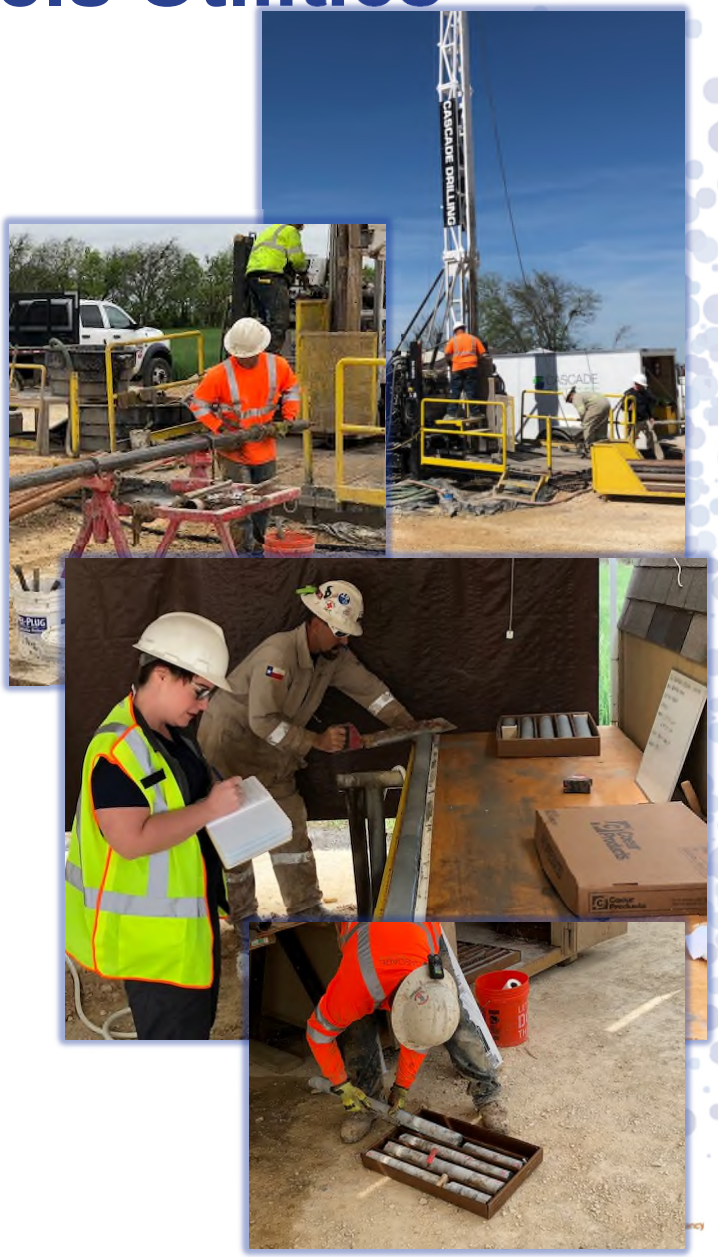
ASR in Texas: City of Victoria

System Components	1 ASR well (retrofit of existing City production well)
Capacity	2.1 MGD – Recovery 0.8 MGD – Recharge
Source	Treated surface water
Storage Zone	• Evangeline formation of Gulf Coast Aquifer
Primary Application	• Meeting peak demand • Storage for drought • Deferral of SWTP expansion

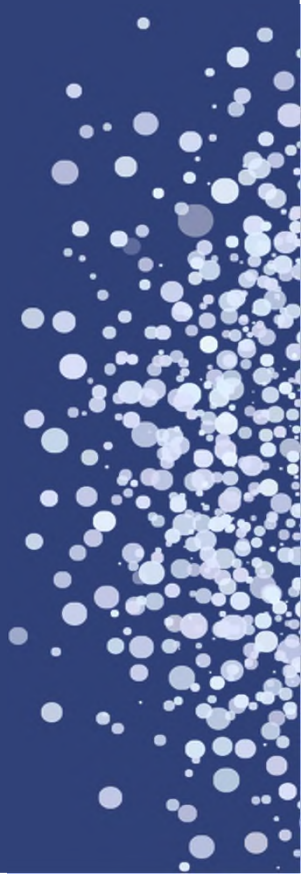
ASR in Texas: New Braunfels Utilities

Demonstration Project

System Components	• 1 ASR well • 4 monitoring wells
Capacity	1.0 MGD – Recovery 0.5 MGD – Recharge
Source	PWS Blend (treated surface water and groundwater)
Storage Zone	Saline Zone of Edwards Aquifer
Primary Application	• Meeting seasonal peak demand • Storage for drought



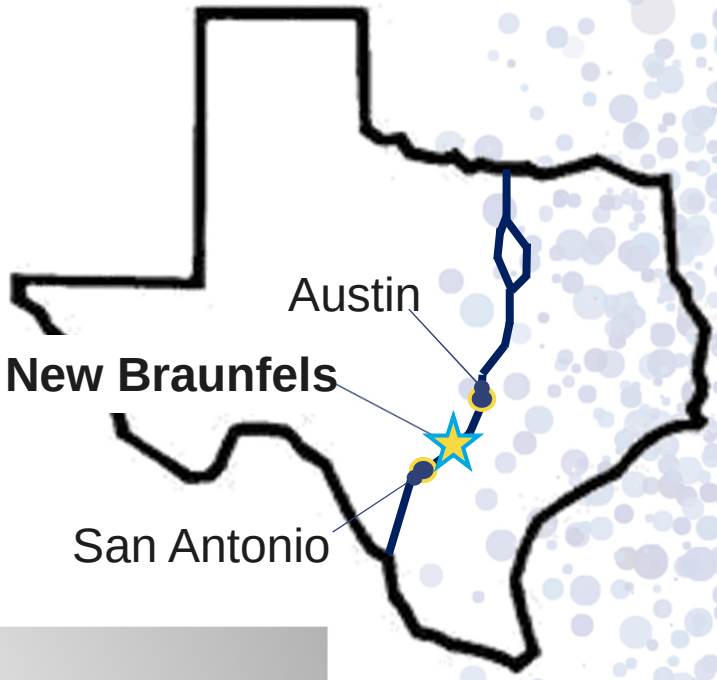
The New Braunfels Situation



NBU Service Area Forecasted Population

Growth projections based on analysis of similar fast-growing communities along IH 35 corridor

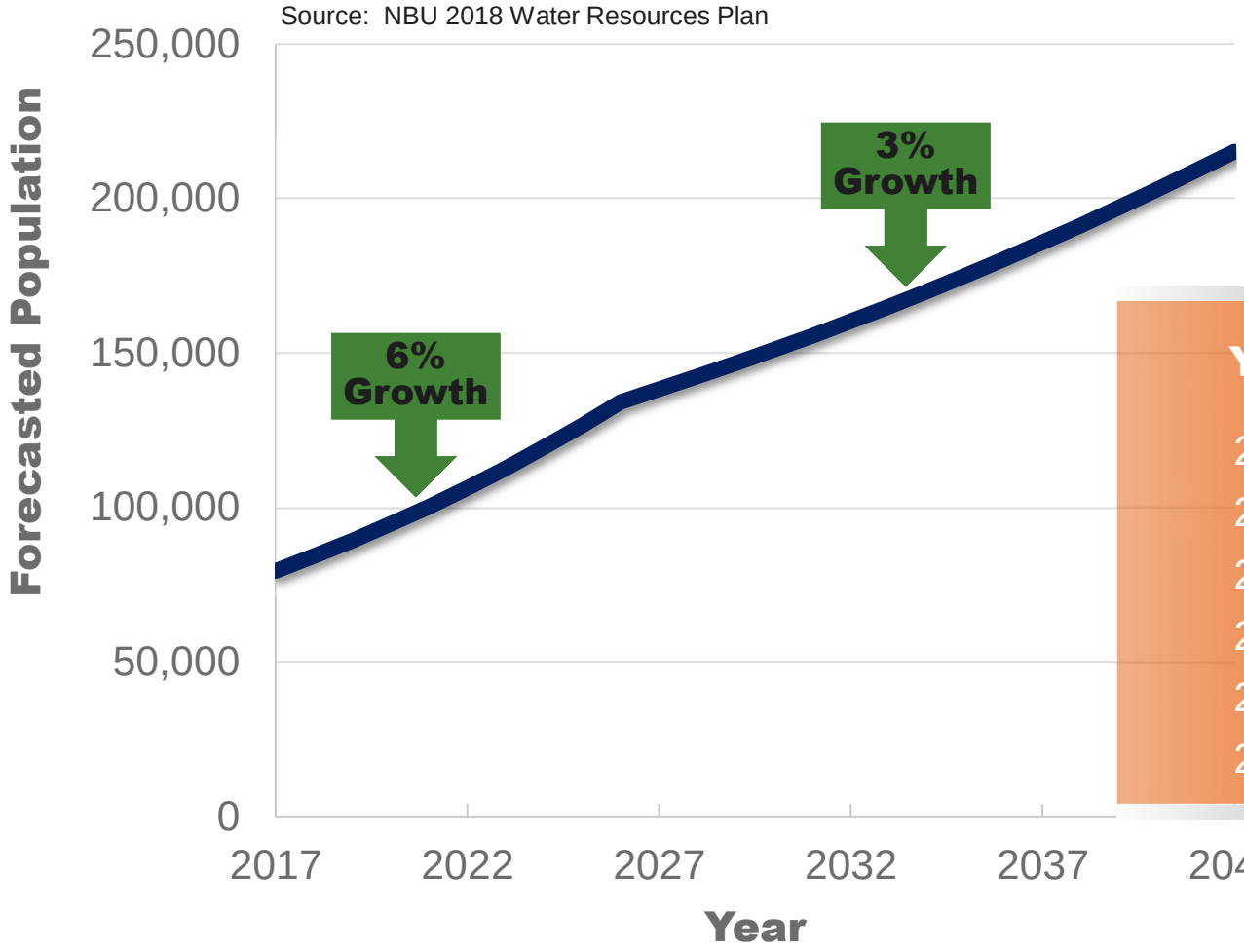
Located between Austin (to the north) and San Antonio (to the south)



New Braunfels is one of the fastest growing communities in the United States.

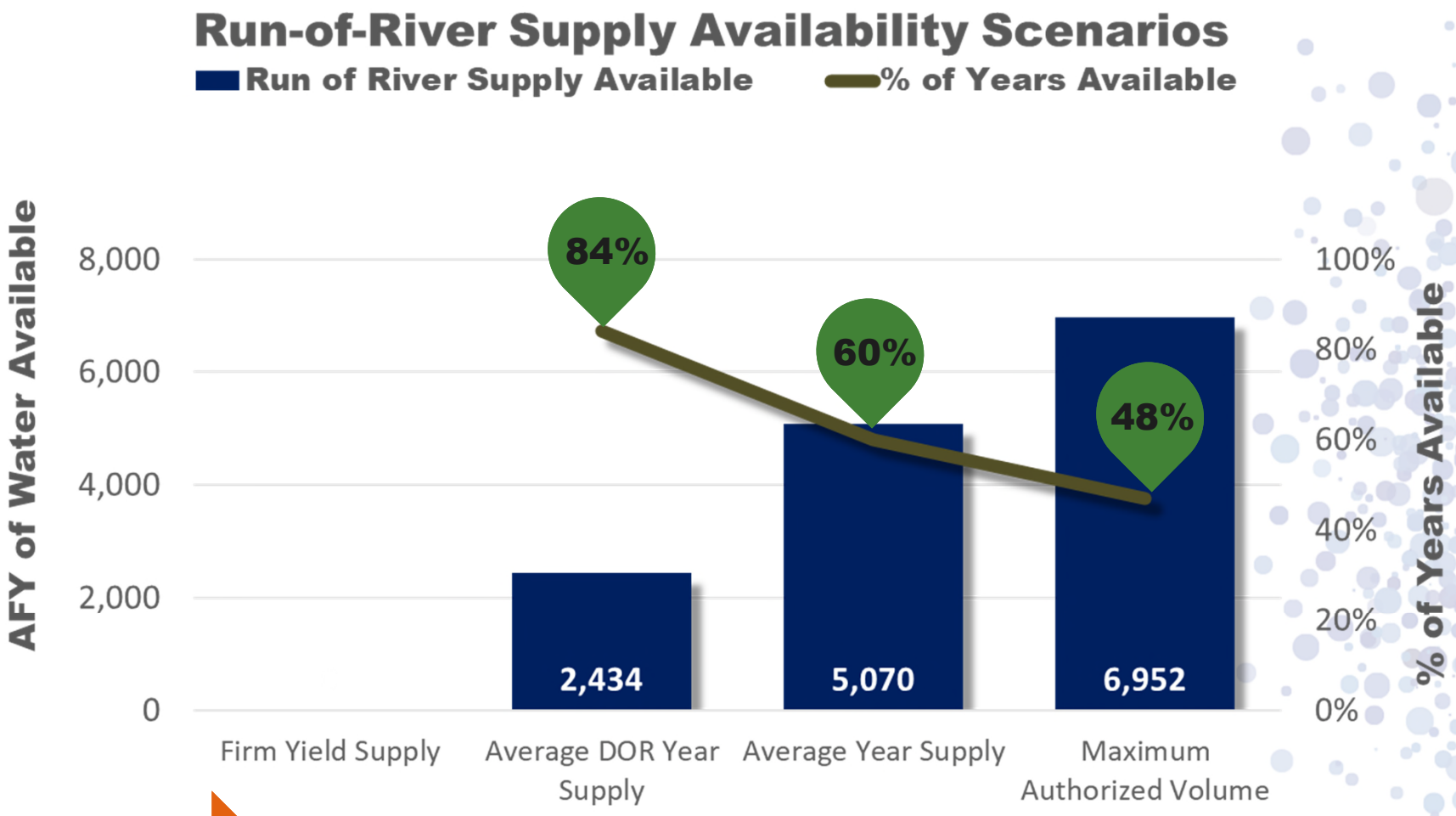
NBU Service Area Forecasted Population

Source: NBU 2018 Water Resources Plan



Year	Forecasted Population
2017	79,400
2020	94,600
2025	126,500
2030	151,000
2035	175,000
2040	202,900

Water Supply Availability

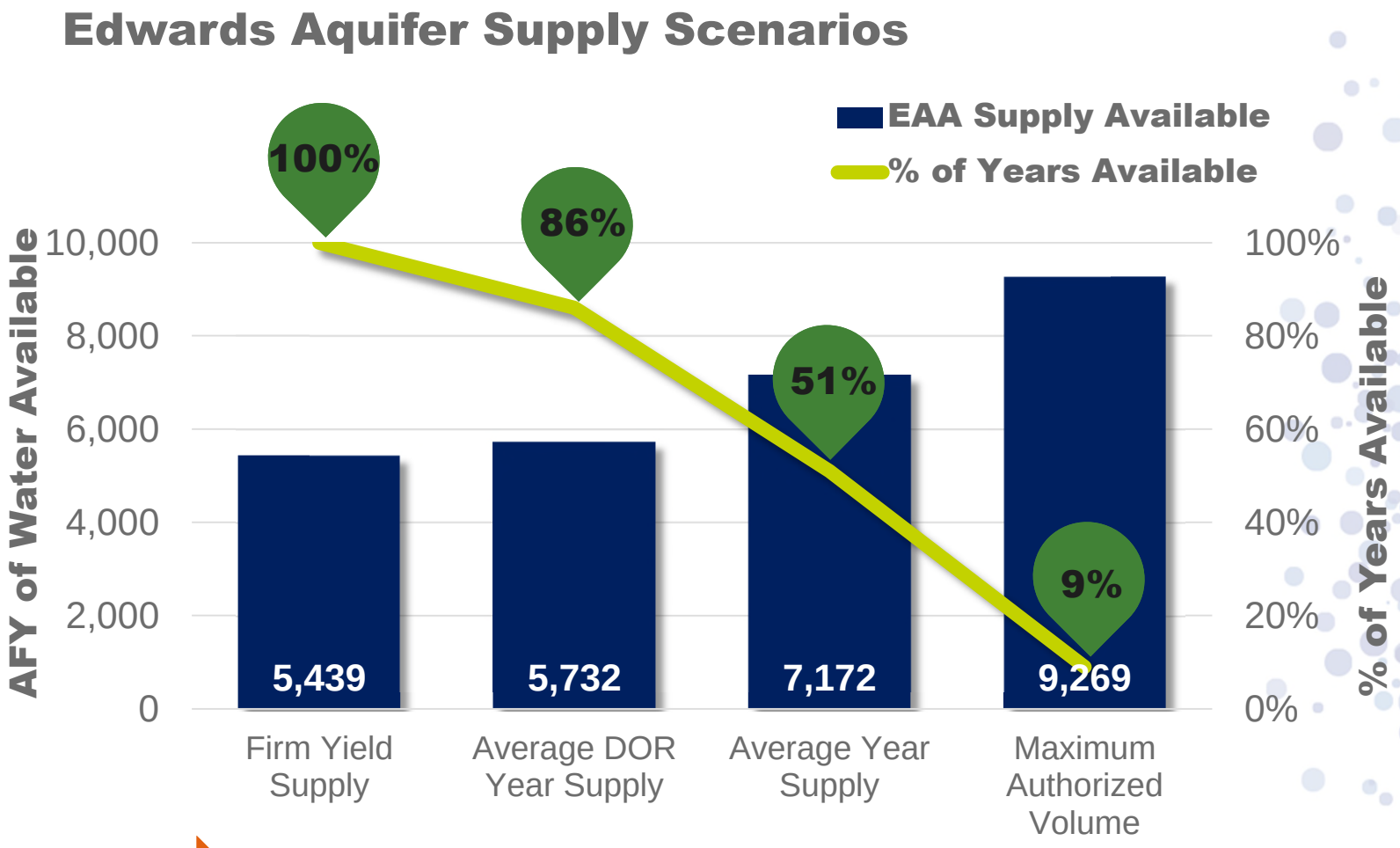


Full Run-of-River Supply Available Approximately 50% of Years

Groundwater Sources

	Quantity (AFY)
 **Edwards Aquifer** Subject to restrictions by EAA	9,269
 **Trinity Aquifer** Firm supply through DOR	3,700
Total Groundwater Authorizations	**12,969 AFY**

Groundwater Sources

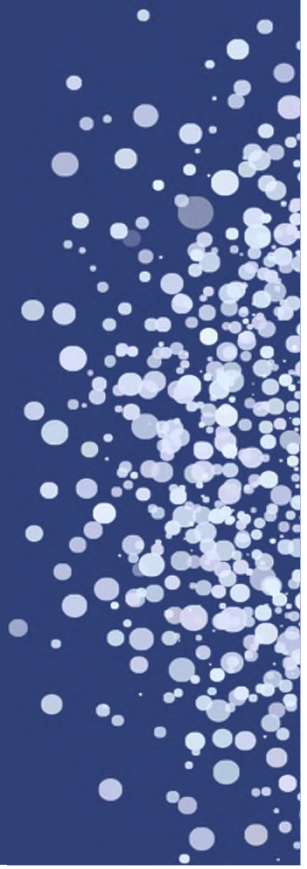


Full Edwards Aquifer Supply Available Approximately 9% of Years

NBU Vision for ASR

- **Primary Goal**: provide storage of treated drinking water to supplement supply during drought periods when current supplies are curtailed.
- **Secondary**: used as a buffer for peak seasonal demands or as a water supply resiliency measure.
- Build out target is 9 MGD of recovery capacity with a recharge rate of 4 MGD.

Site Selection



Site Selection: Hydrogeology

- **Depth**: Typically, both construction and operational costs increase with depth
- **Formation confinement**: Well-confined zones improve containment of injected water
- **Transmissivity**: Higher transmissivity allows higher injection and recovery rates
- **Water Quality**:
  - Fresh water means that native groundwater recovery is of less concern
  - Storage in brackish aquifers requires more design considerations

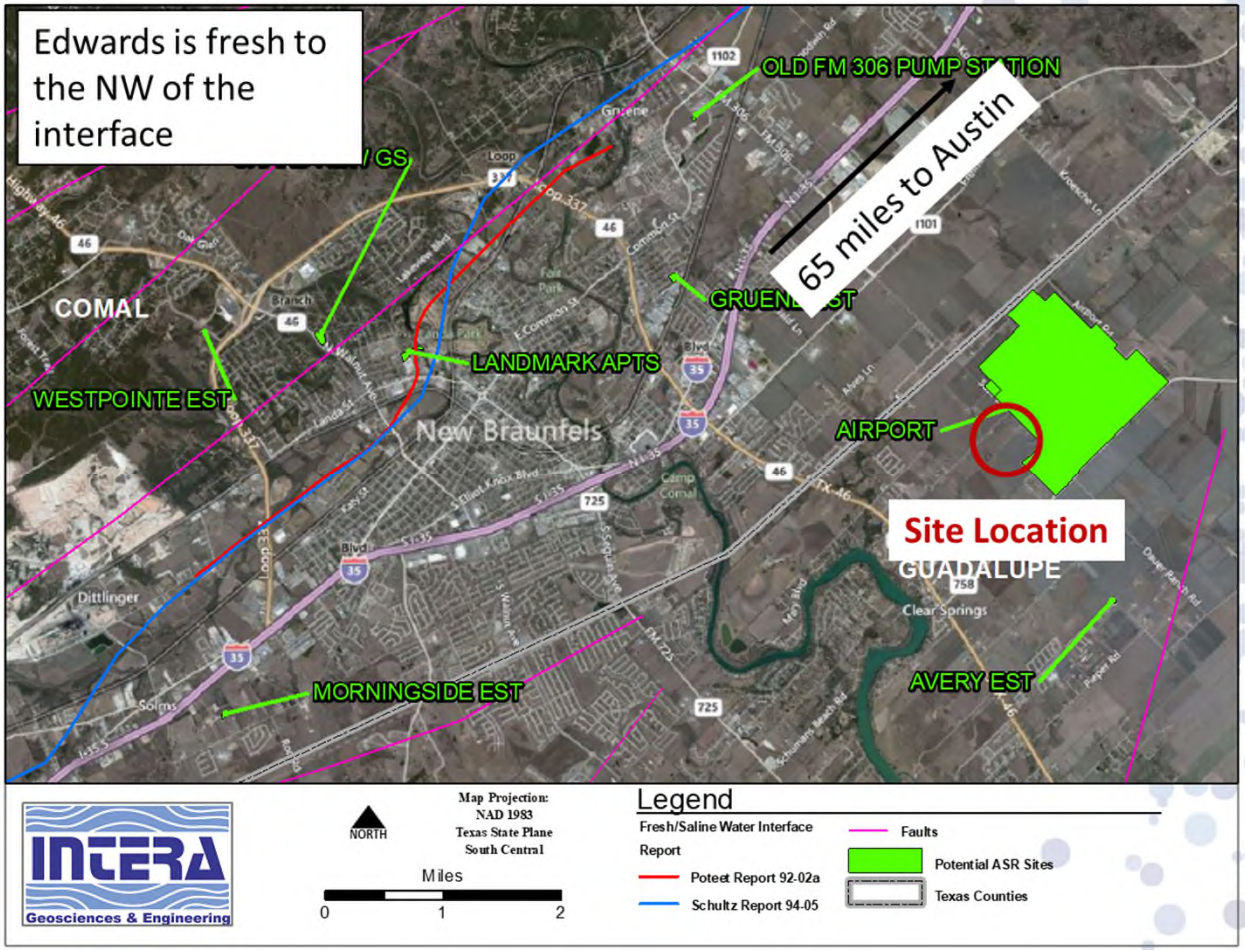
Site Selection: Summary of Hydrogeology

Formation	Approximate Well Depth (ft)	Confinement	Transmissivity	Water Quality
Brackish Edwards	1000	Moderate	Uncertain, likely high	Brackish, ~4,000-5,000 mg/L
Middle Trinity (Lower Glen Rose)	1500	Moderate	Moderate	Typically Fresh, < 1,000 mg/L
Lower Trinity (Lower Sligo)	2000	High	Uncertain, likely low to moderate	Uncertain, likely brackish

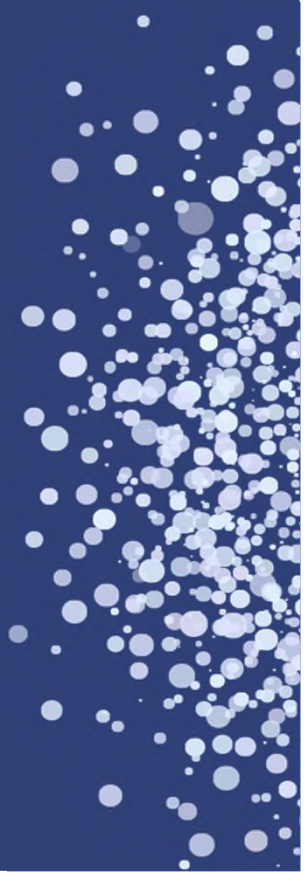
- **Brackish Edwards (instead of fresh) targeted for regulatory reasons**
- **Hydraulic properties thought to be favorable, but uncertainty requires rigorous field testing**

Site Selection: Airport Site

- Likely favorable hydrogeology in the Edwards
- Accessible city land
- Near existing transmission
- Protected from other wells

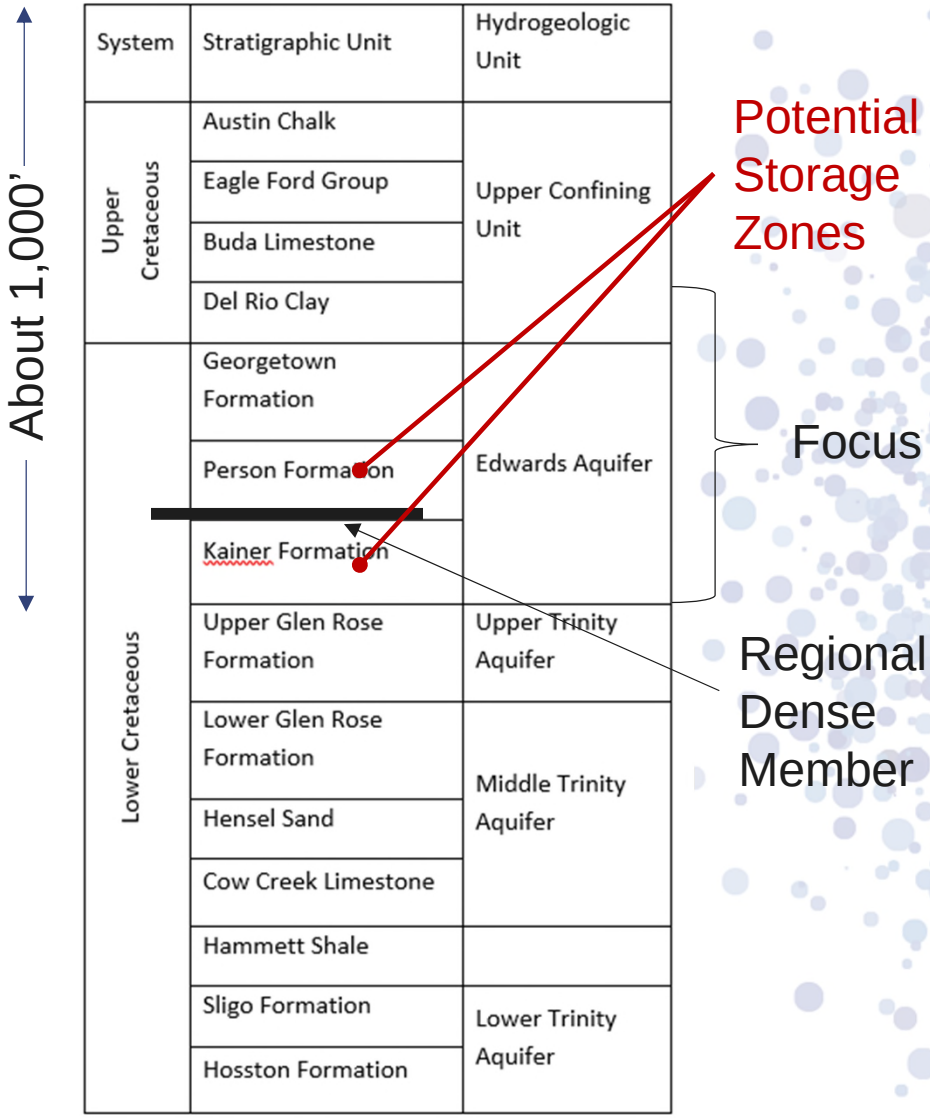


Site Characterization

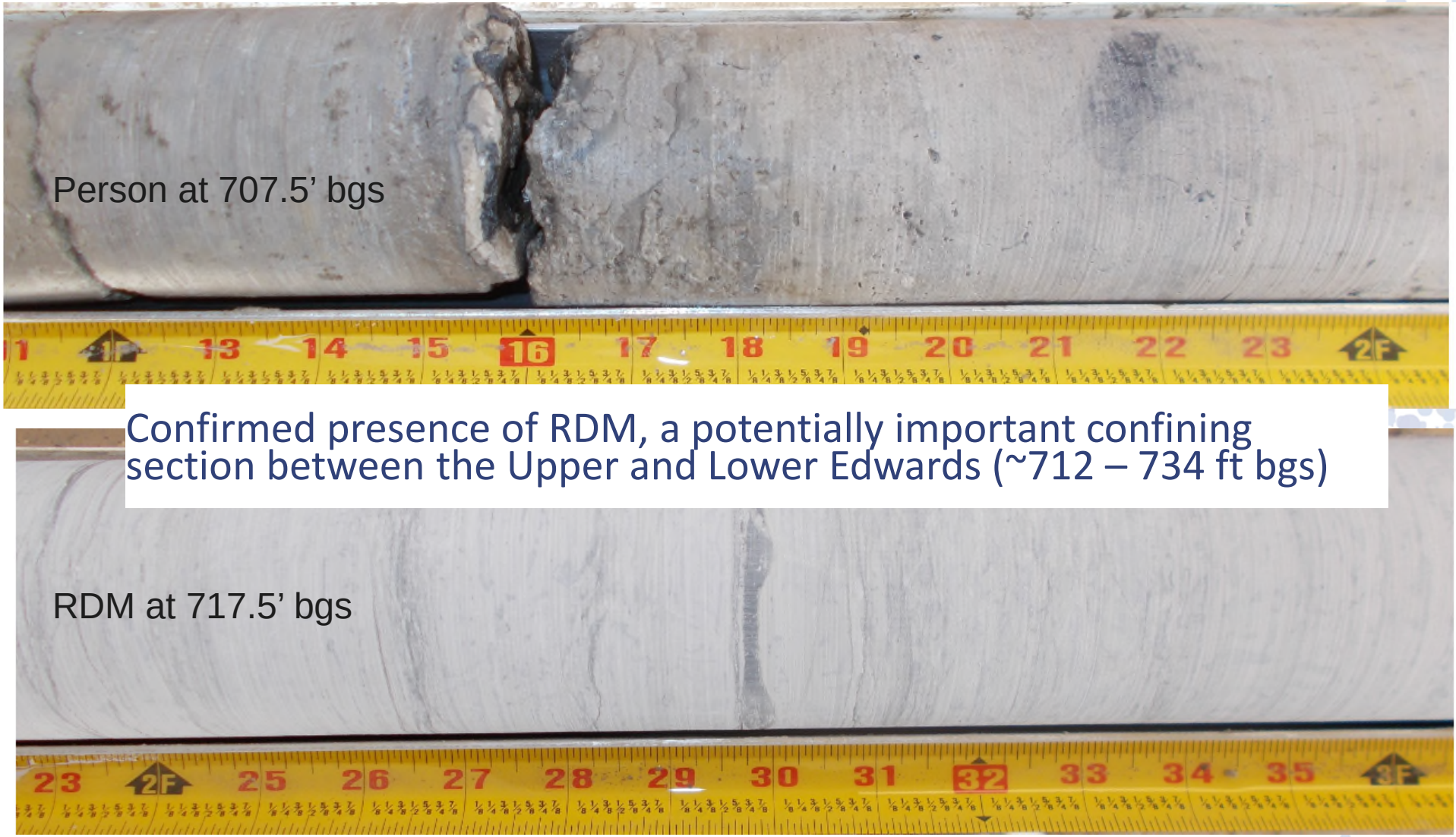


Site Characterization Plan

- Wireline Core
  - Hydraulic properties of confining units
  - Porosity of the potential storage zones
  - Geochemistry of the potential storage zones
- Monitor Wells
  - Hydraulic properties of the potential storage zones
  - Water levels
  - Native water chemistry
  - Future use in ASR monitoring



Wireline Core



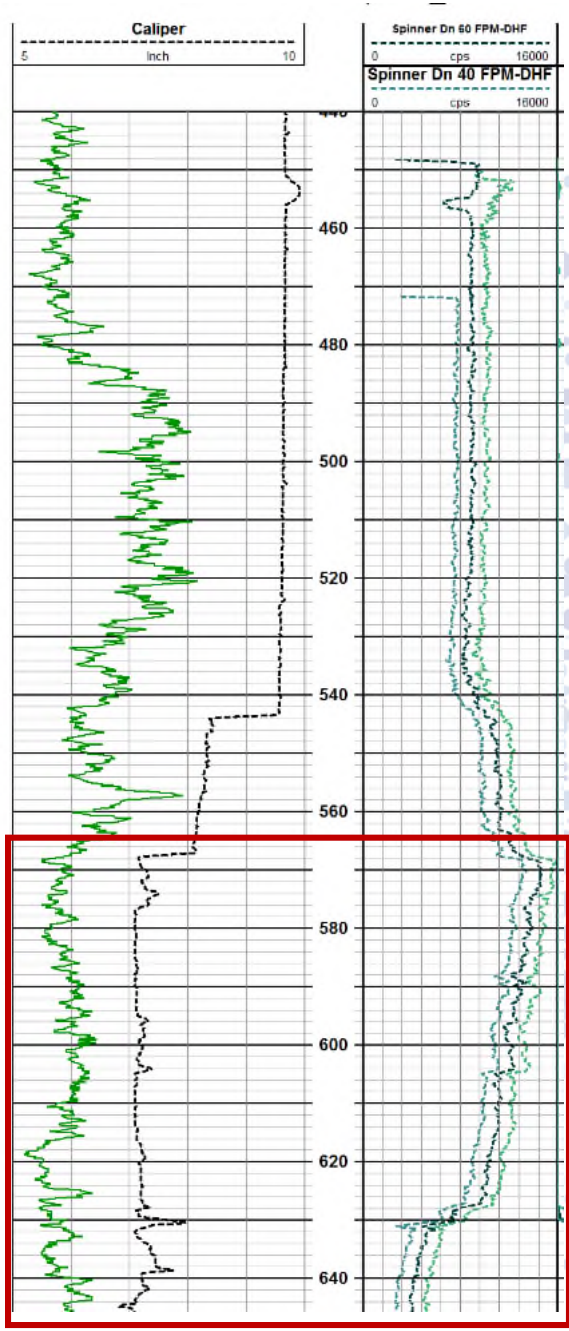
Confirmed presence of RDM, a potentially important confining section between the Upper and Lower Edwards (~712 – 734 ft bgs)

Monitor Wells

- Two wells
- MW-UE-1 above the RDM (545’ to 710’)
- MW-LE-1 below the RDM (735’ to 940’)

MW-UE-1: Productivity

- Upper interval was spinner logged
- Well produced 395 gpm from a 6-3/4” hole, with 37 feet of drawdown
- Specific capacity of 2.8 gpm/ft
- Spinner log showed highest productivity starting at 590’ with a kick at 630’



Groundwater Chemistry

- Sampling of upper and lower intervals gave a TDS of about 10,000 mg/L in both cases
- Mineralogy and geochemistry also analyzed (see TWDB report)
- Some concern about dissolved CO_2 (can cause complaints with customers), lab testing indicated 75 mg/L total dissolved carbon

Characterization Wrap-Up

- Saline Edwards Aquifer appears productive enough at the airport site for ASR
- Confinement of the Upper Edwards appears favorable above and below
- No obvious red flags in water chemistry (buffer zone will be critical due to native water quality)

New Braunfels Utilities:
Aquifer Storage and Recovery
Demonstration Project

By Arcadis U.S., Inc., ASR Systems LLC, INTERA Incorporated

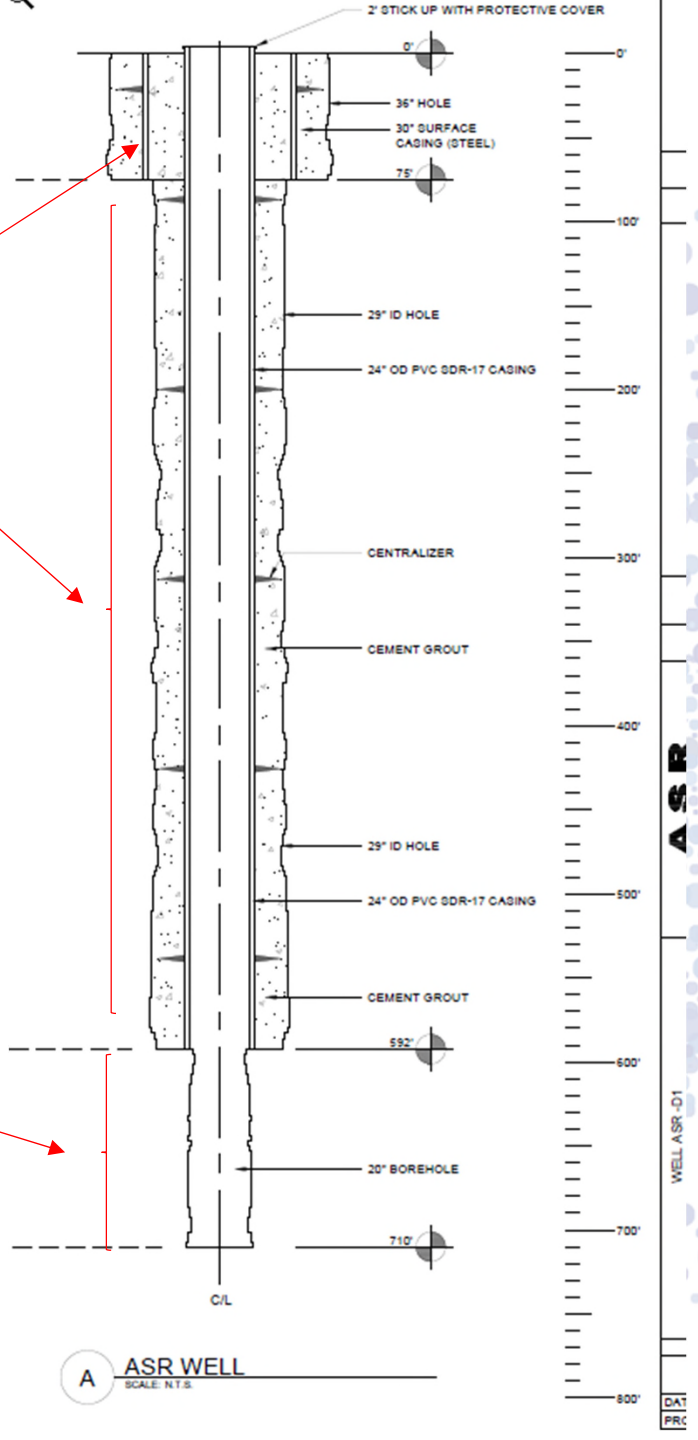
September 2018

DRAFT

ASR Demonstration Well Construction

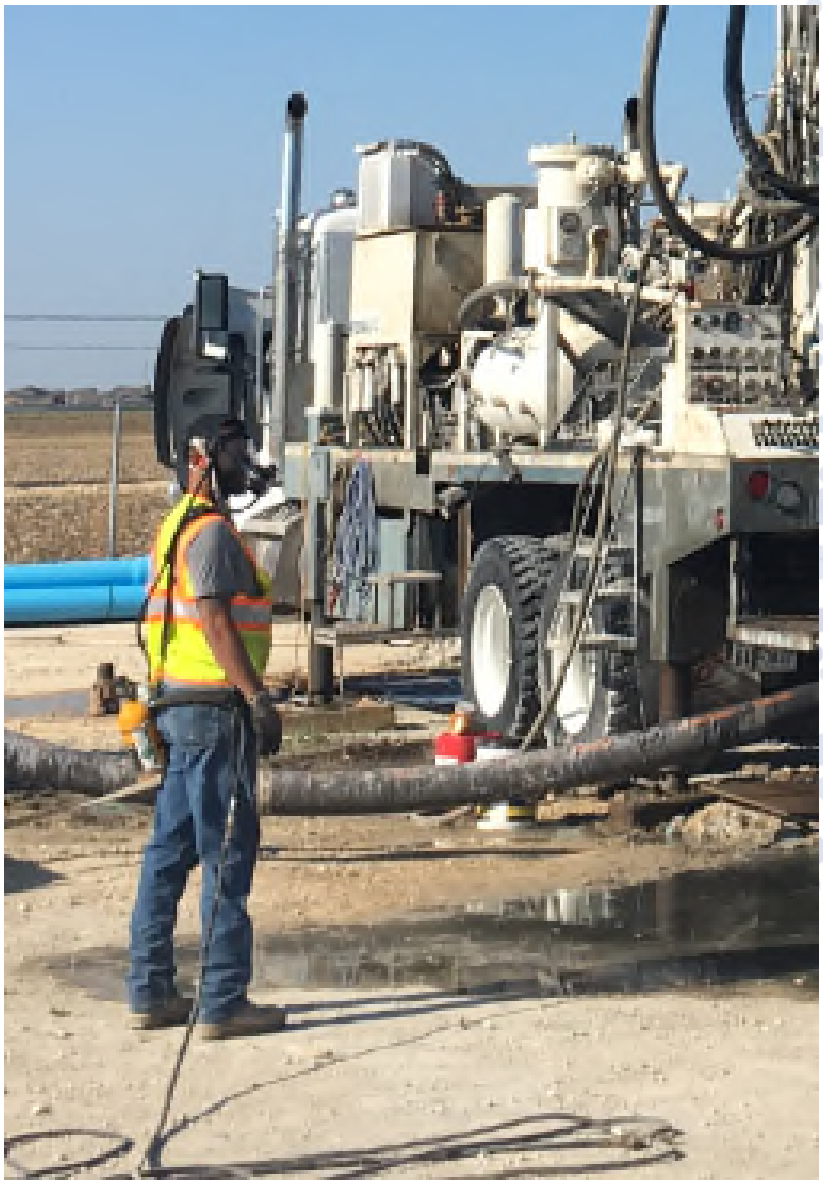
ASR Well ASR-D1

- 30” surface casing
- 29” to 592’, 24” PVC casing
  - PVC resists corrosion from brackish environment
  - Tricky grouting, heat of hydration can soften PVC
  - Grout in stages
- 20” open hole from 592’ to 710’



MW-LE-1 (Lower)

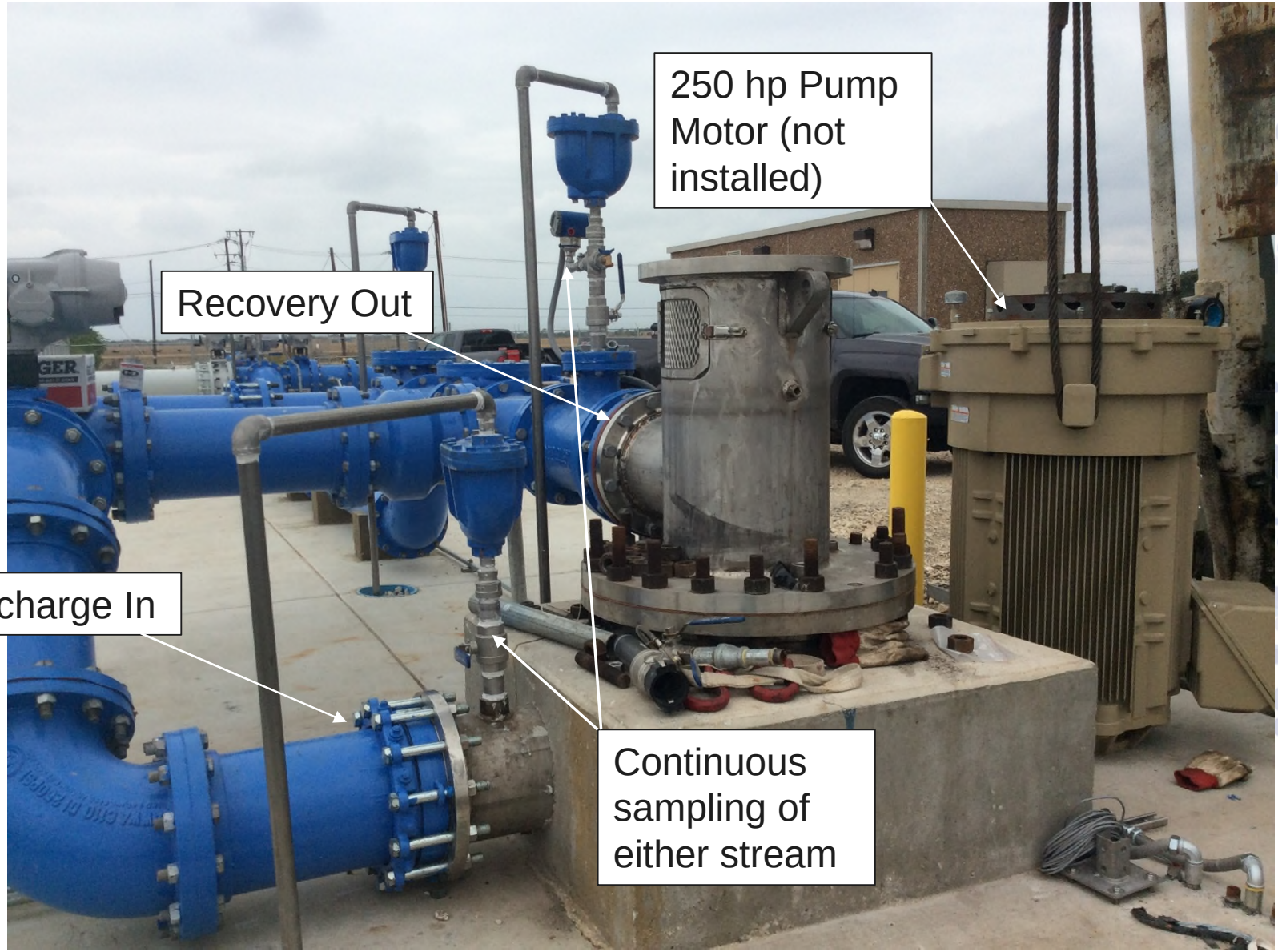
- High levels of H2S over wellhead and frac tank
- Brought in H2S specialists (Cam Safety) to equip and monitor for H2S
- PPE slows drilling progress to some extent. Not recommended for summer months (in TX).



ASR-D1: Acidization Required

- After initial development, productivity did not meet expectations
- Acidization performed
- Results exceeded expectations
- 1000 gpm after acidization (doesn't always work that well!)

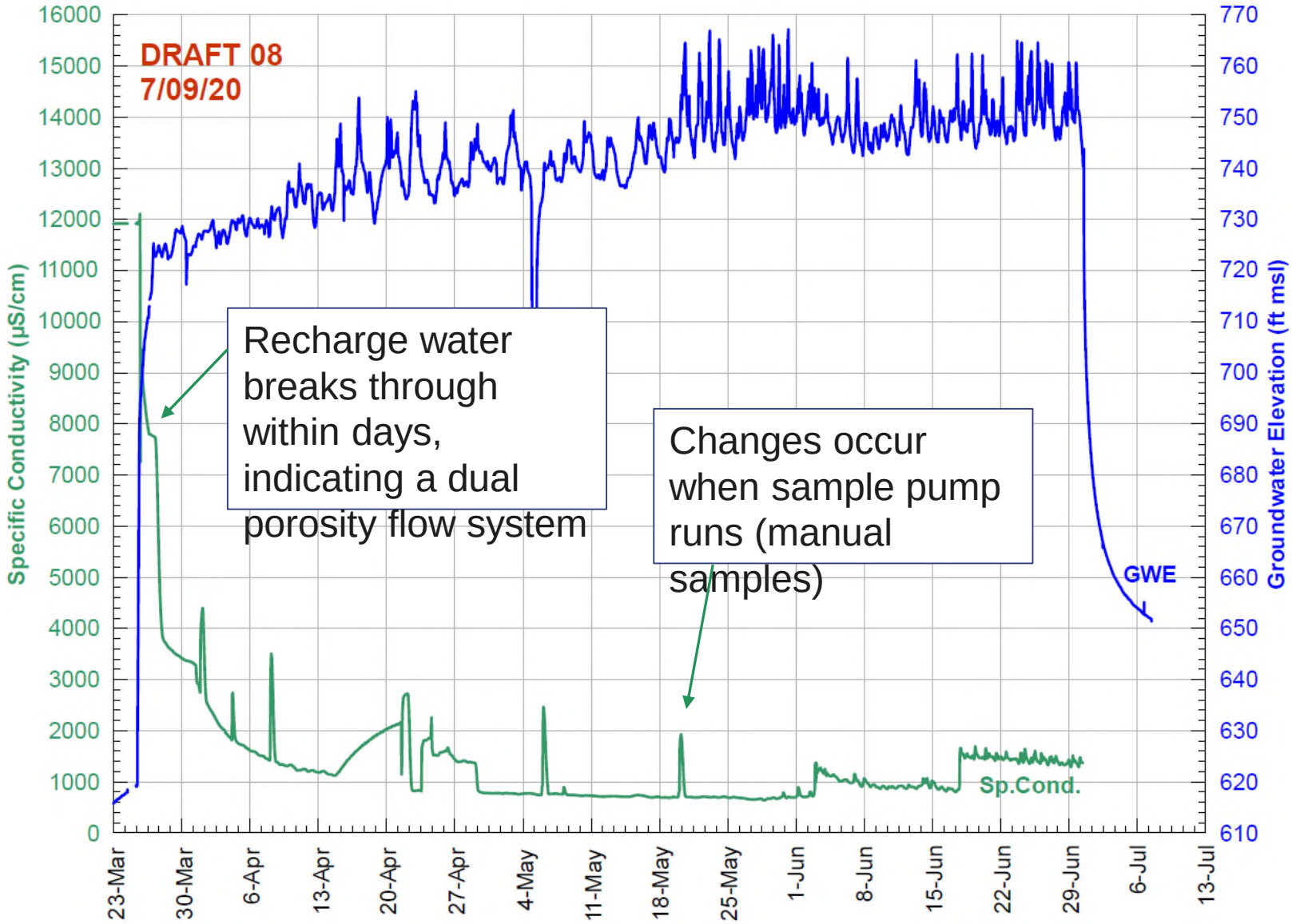
ASR-D1: Wellhead



ASR-D1: Formation Testing

- Formation testing included long-term porosity test
- MW-UE-1
  - 150’ away from ASR-D1, completed in same interval
  - Monitor breakthrough of recharge water on-site
- MW-LE-1
  - 150’ away from ASR-D1, completed in interval below
- Two other monitor wells 2 miles to the west

Recharge Water Breakthrough



Summary

- Do as much as you can up front to determine feasibility and suitability
  - Analysis of existing hydrogeological information
  - Identify a suitable site
  - Wireline coring
  - Water chemistry
- Prepare for the unexpected
  - Contract allowances for specialty services
  - Authorized contingency to prevent delays

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