The SAWS Story:
Developing Brackish Desal in Texas

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Texas Desal 2017
September 21, 2017

25 WATERFUL YEARS
San Antonio Water System

MAKING SAN ANTONIO WATERFUL

SAWS Overview / Timeline / Big Lessons

Duane Bryant, P. E.
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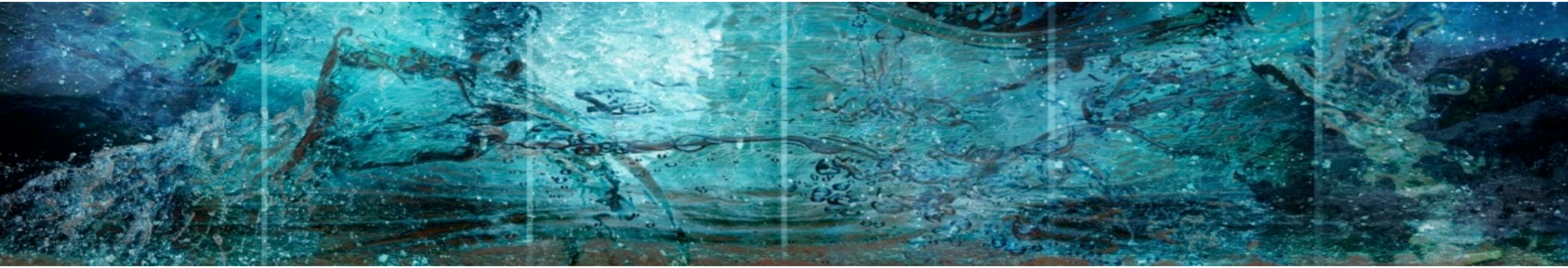
Outline

- Water Challenges
- Project Background
- Project Challenges
- Facility Highlights

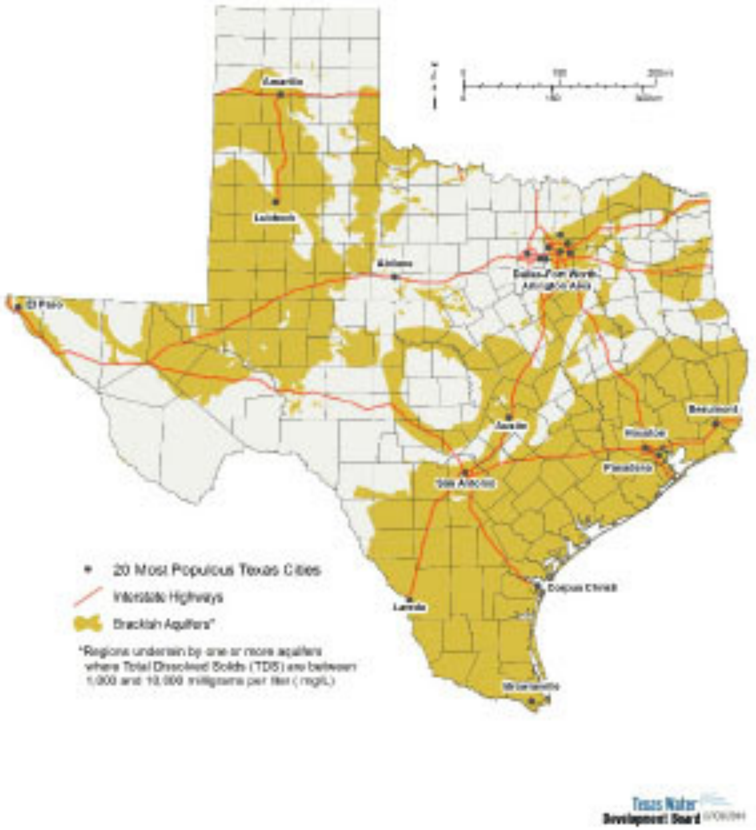


Water Supply Challenges

Why Brackish Inland Desalination

- Large volumes of available brackish water
- Resource close to San Antonio
- Identified in the SAWS 2005 Water Management Plan
- Diversification
- Untapped resource

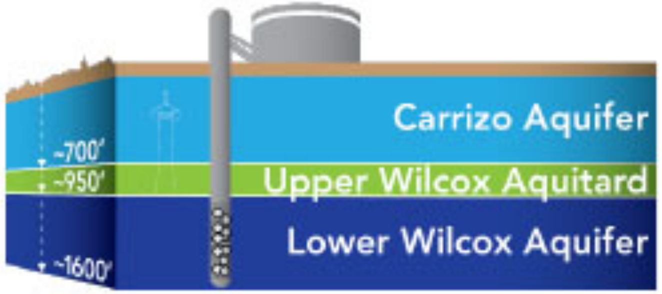
Brackish Aquifers of Texas



Desalination Program

General Information

- Phase I (2016) – 12 MGD – 13,440 Acre-feet / year
  - (~53,000 Households)
- Source Water
  - Lower Wilcox Formation
  - 12 Production wells (~1,500' avg. depth)
- Treatment Process
  - Reverse Osmosis
- Concentrate Disposal
  - 2 Injection wells (5,000' avg. depth)



Project Cost

Phase I

- Project Cost: $192.7 million, $1,177 $/AF
- Began producing water November 9, 2016

Challenges

- State and Local Groundwater Regulation
- Public Perception
- Stakeholder Buy in
- Funding/Value Engineering
- Real Estate
- **Concentrate Disposal**
- **Design**
- **Construction**
- **Operational**

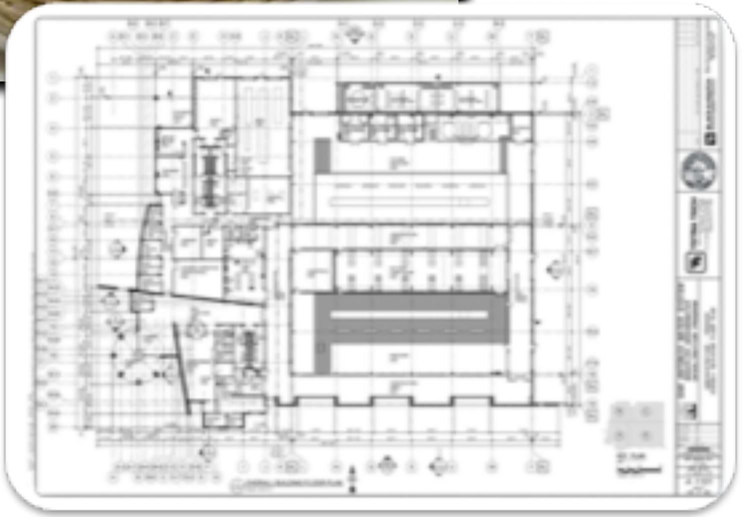
Concentrate Disposal

Options Considered

Design

Challenges

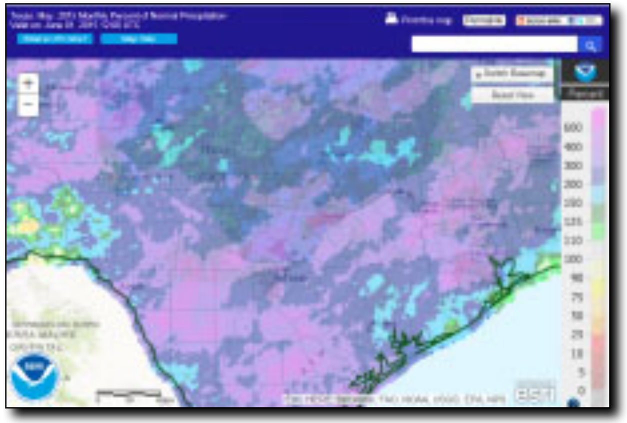
- Prevent Membrane fouling
  – Open System vs. Closed System
  – Pre-treatment
- Finish water quality standards
- Short design timeline
  – Multiple sub-consultants



Construction

Challenges

- Budget
  - Managing a budget without owner contingency
- Schedule
  - Record Rainfall (2 yrs.)
- Complicated Construction
  - 13 Work Packages



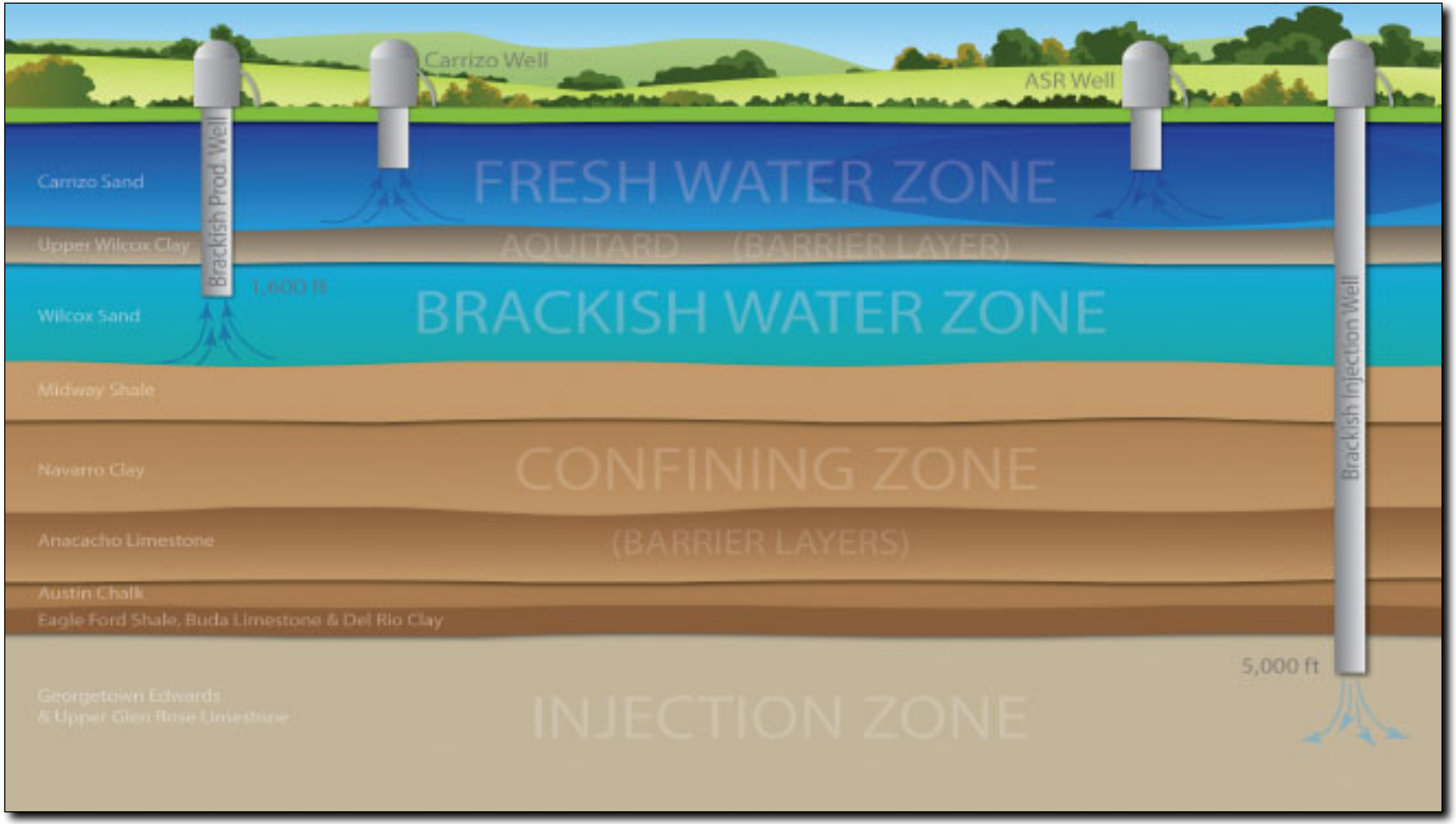
Operational

Challenges

- Learning curve
  - Fully automated plant
  - Bring in operators early
  - 1 month RDT & 3 months commissioning phase
- Operational
  - Raw Water
    - Cartridge Filters/Turbidity
  - Fouling
  - Meeting Finished Water Goals

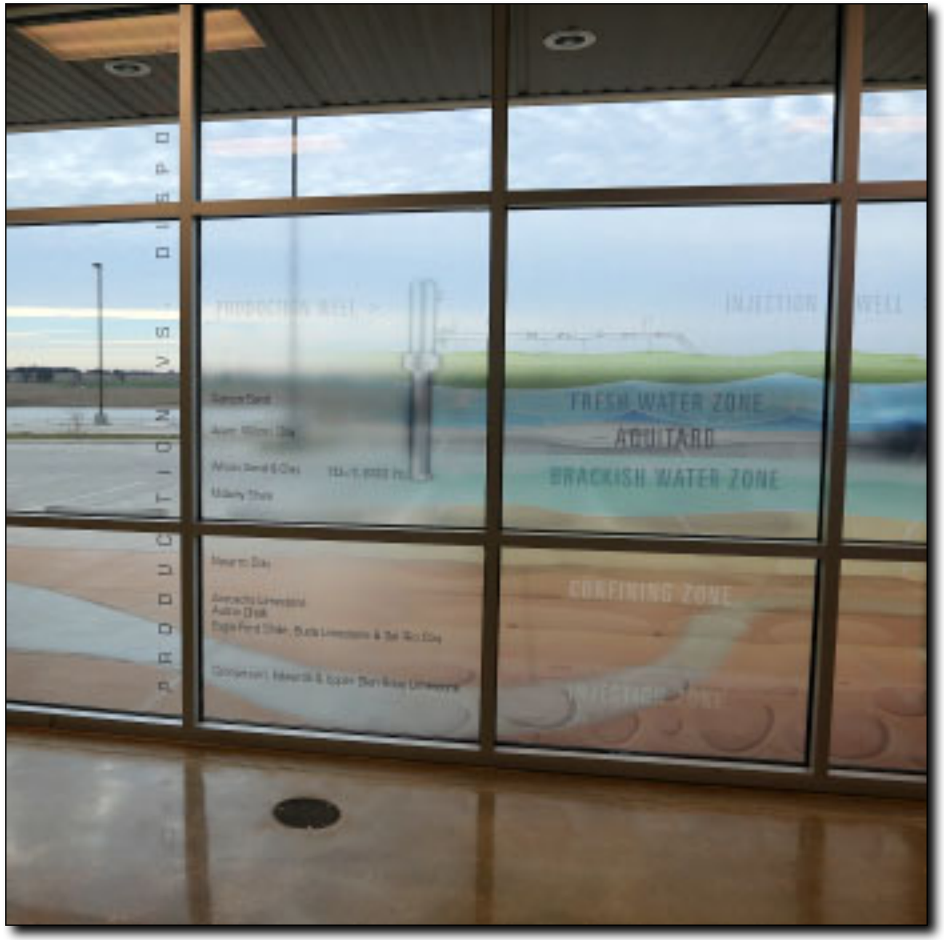
Treatment Facility

Three Water Supplies at H_2Oaks



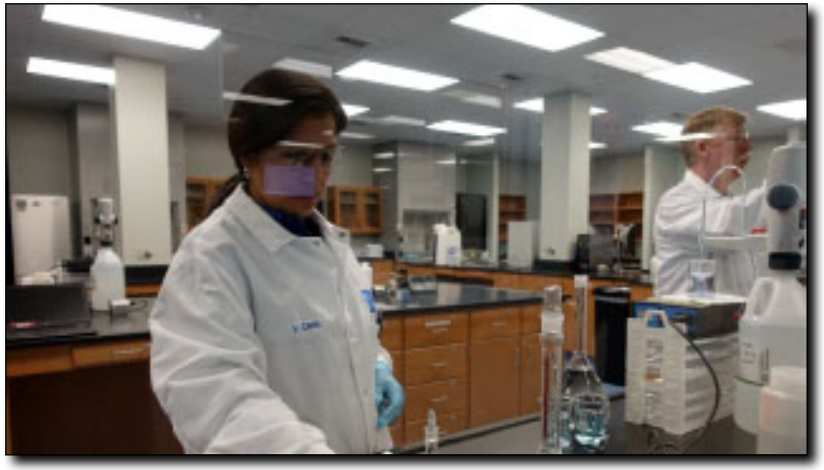
Water Supply and Educational Center

Education and Outreach



Water Supply and Educational Center

Education and Outreach



Grand Opening Festivities

January 27, 2017

Acknowledgements

BLACK & VEATCH

ZACHRY PARSONS

TETRA TECH

LBG GUYTON

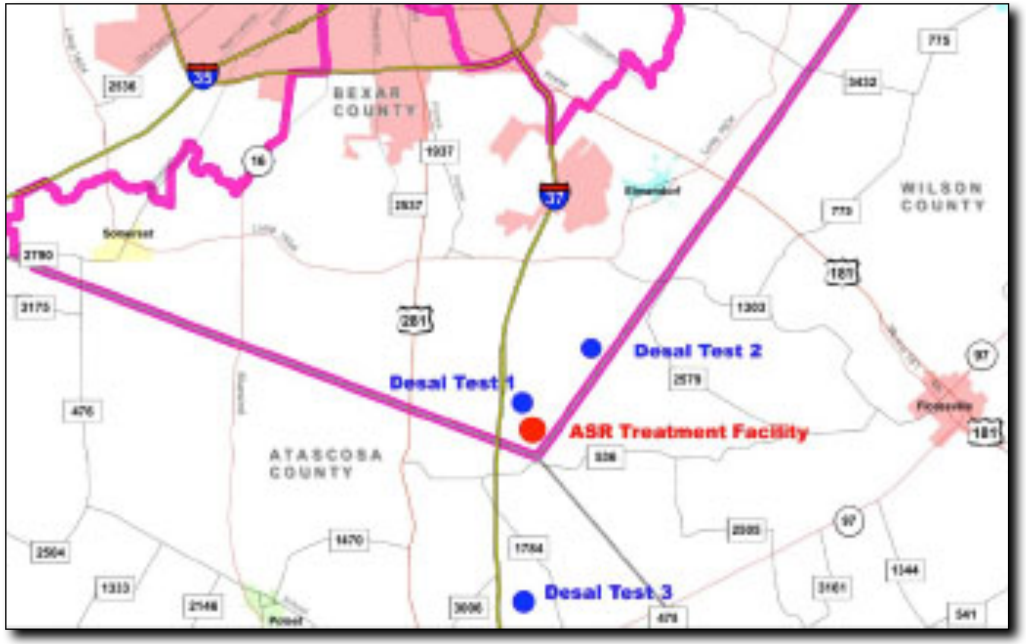
AECOM

GAI
Gupta & Associates, Inc
CONSULTING ENGINEERING

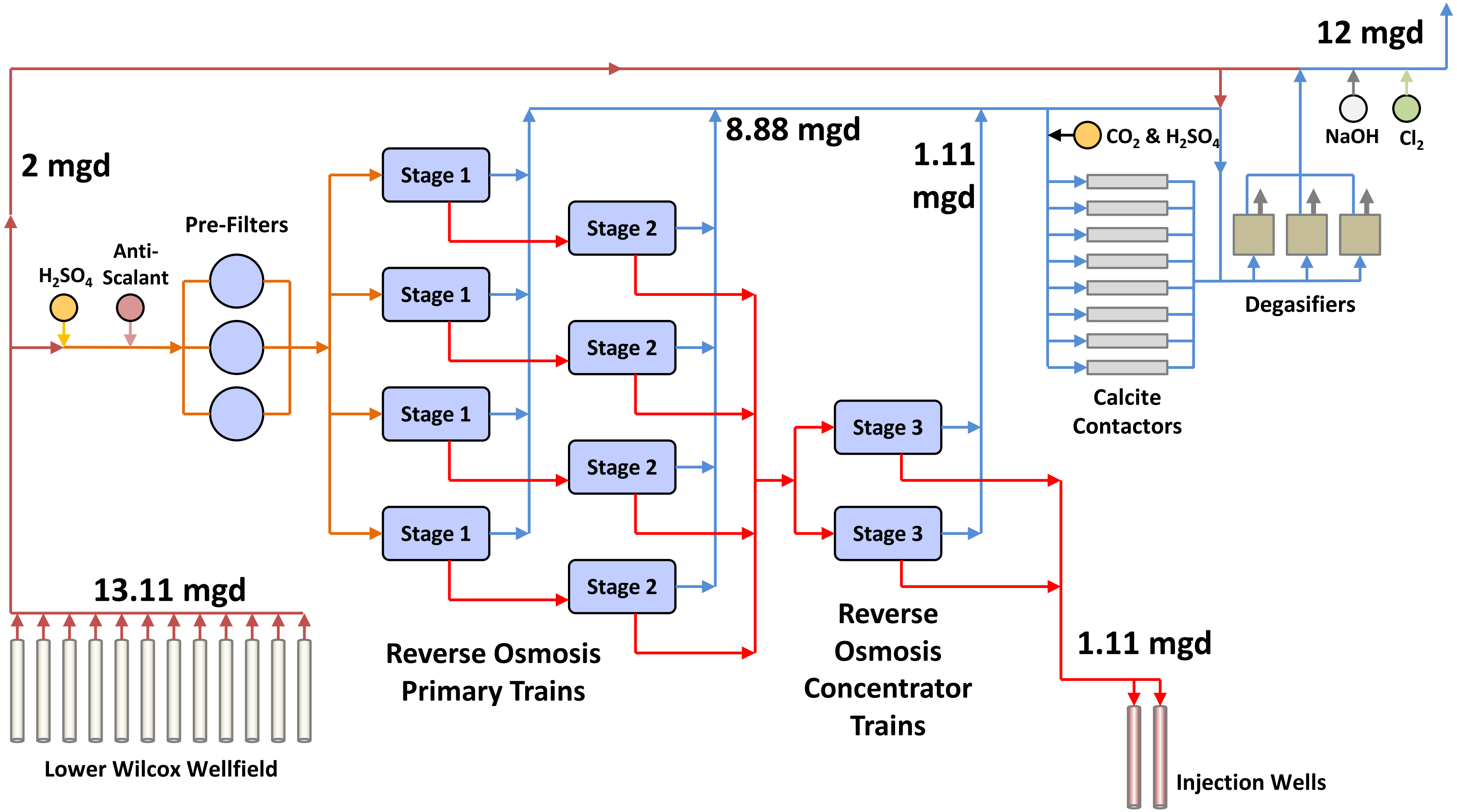
Reverse Osmosis System Design

Saqib Shirazi, P. E. PMP
Project Manager, Desalination and Integration, SAWS

SAWS Brackish Groundwater Desalination Plant



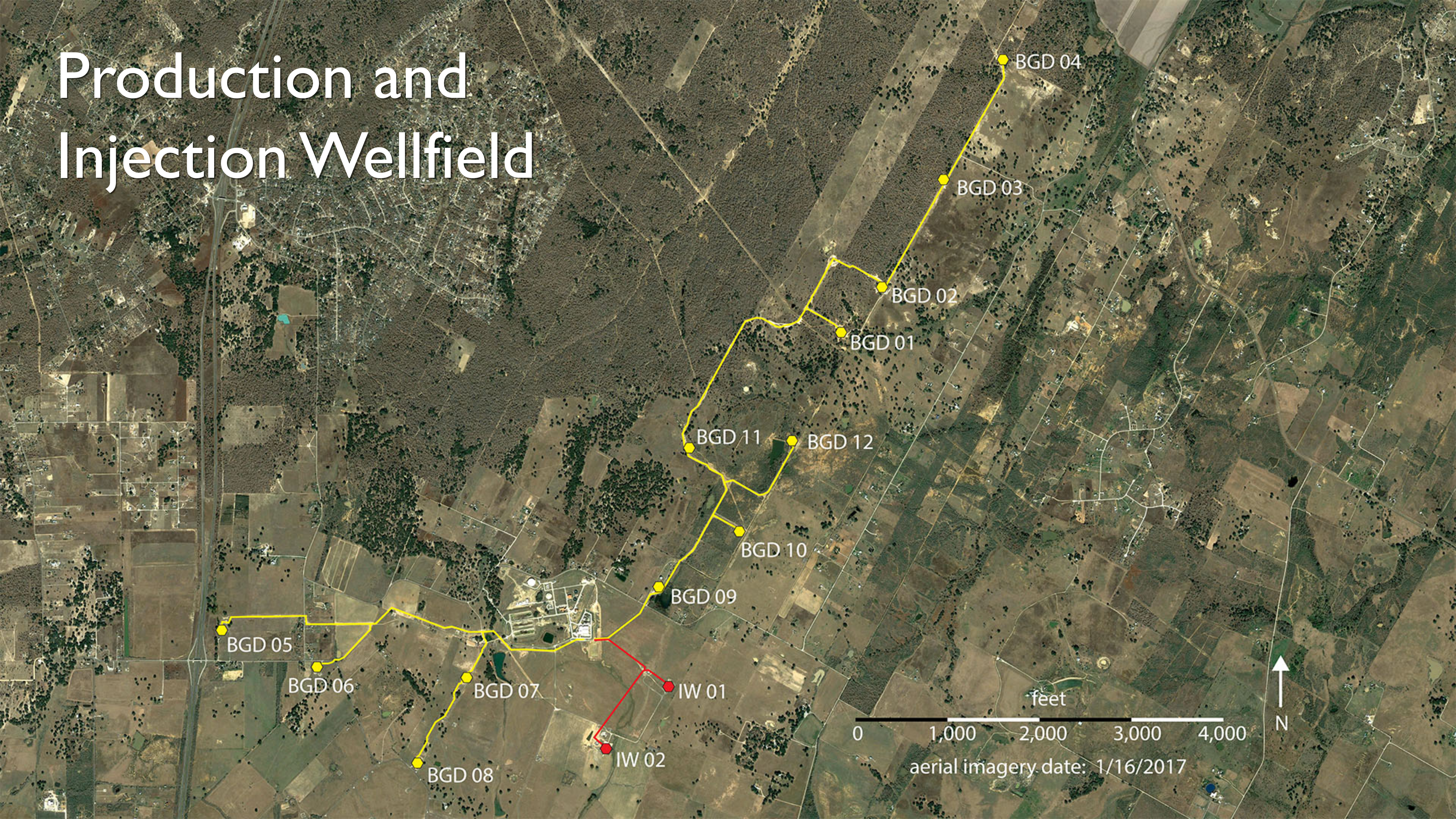
Process Diagram



Raw Water Supply

- Wilcox Aquifer – Brackish Water TDS Approx. 1,500 mg/L
- 12 production wells
- Approximately 11 miles of conveyance pipeline
- Production Well Details:
  - Maximum Flow: 700-1,000 gpm
  - Well Depth: Approx. 1,500 ft
  - Well Pump Depth: up to 750 feet BLS

Production and Injection Wellfield



Raw Water Supply Well Operation

- Screened production zone with gravel packing due to fine sand aquifer
- On-line turbidimeters at each well to provide general indication of water quality
- Variable speed well pumps for anticipated future draw down
- Three (3) supply wells required for each Primary RO skid
  - 1st and 2nd wells maintain flow set point
  - 3rd well maintains pressure set point at WTP
- Well Startup Sequence:
  - Timed pre-lubrication of pump shaft bearings prior to start
  - Pre-flush to waste operation (typically 15 minutes, but adjustable)
  - Multiple Timed Events = Normal start-up sequence is a time consuming process

Conveyance Pipeline

- "Closed System" conveyance pipeline design was implemented to prevent air contact with the raw water
- During plant shutdown periods, one well stays running to maintain pressure in pipeline
- Pre-lubrication water is normally taken from raw conveyance pipeline, select wells are equipped with a backup potable water pre-lube supply (for power failures)
- Plant provides on-line turbidity and ORP sampling of flushed water (prior to chemical or physical pretreatment)

Pre Treatment

- Scale Inhibitor/Antiscalant
- pH Adjustment to 6.5 using Sulfuric Acid
- Cartridge Filters
  - 3 x 7.0 MGD Units
  - 14.0 MGD with One (1) Unit Offline
  - 5-Micron Nominal Polypropylene, String Wound, SOE, 40-inch

Operation Scenarios

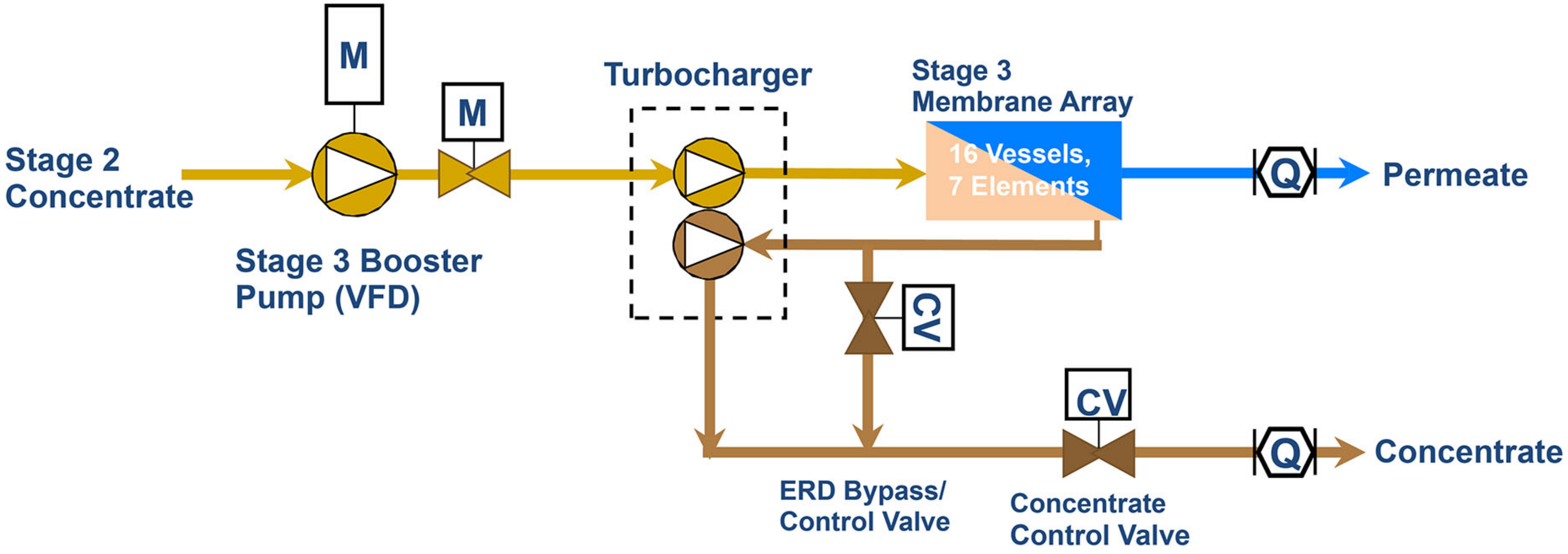
Permeate Flow (mgd)	Primary RO Units Running	Concentrator RO Units Running	Primary Concentrate Bypass Flow (mgd)	Final Concentrate Flow (mgd)	Overall Recovery
2.22	1	0	0.55	0.55	80%
4.44	2	0	1.11	1.11	80%
5.0	2	1	0	0.55	90%
7.22	3	1	0.55	1.11	86.75%
10.0	4	2	0	1.11	90%

Reverse Osmosis Treatment

- Primary RO
  - Capacity: 2.22 MGD
  - 80% Recovery
  - 4 Skids in Initial Phase, 10 Skids at Buildout
  - Array: 40:20 Vessels, 7-Elements in Series
- Concentrator RO
  - Capacity: 0.55 MGD
  - 50% Recovery
  - 2 Skids in Initial Phase,
    4 Skids at Buildout
  - Array: 16 Vessels,
    7-Elements in Series
  - Expandable to 20 Vessels

Dow FilmTec BW30-400
(34 mil spacer)

Energy Recovery Device



Post Treatment

- Calcite Contactors – Calcium and Alkalinity Addition
- Raw Water Blending – Supplemental Alkalinity & Hardness
- Degasifiers –Excess CO_2 Removal
- Sodium Hydroxide – Final pH Stabilization
- Chlorine – Disinfection

Calcite Contactor System

- Up to 30% Side Stream of 10 MGD of RO Permeate
- TomCO Pressurized Solution Feed System (PSF)TM used for efficient CO_2 feed to the influent water stream
- Sulfuric acid feed for supplemental pH adjustment and backup to CO_2

Post Treatment – Brackish Water Water Blending

- Incorporates Both Raw Water Blend AND Calcite Contactors for Remineralization
  - With no raw water blending, finished water calcium and alkalinity goals can still be attained through operation of calcite contactors
  - With raw water blending, chemical use (CO_2, calcite media) in the calcite contactors can be reduced

Calcite Contactor Piping Gallery

Raw Water Blend (Bypass) Control Valve

Clean-In-Place

- Two (2) 900 gpm Cleaning Pumps, VFD Controlled
- Two 4,500 gal Mixing Tanks
- Cleaning Capacity: Entire 1st stage (40 vessels)
  - Upsized Piping and Tanks
  - Hard-Piped to RO Skids
- Catwalk Tank Access for Chemical Loading from Mezzanine Storage Area
- System Flexibility:
  - Immersion Heaters and Mechanical Mixers on Both Tanks
  - Cleaning pumps can recirculate tanks for mixing or transfer solutions

Injection Wells for Concentrate Disposal

- Two injection wells
- Injection Well Details:
  - Well Depth: 5,000 ft
  - Avg. Flow: 500 gpm (30 day avg)
  - Instantaneous Flow: 1,000 gpm
  - IW Pressures: 775 psi max, 150-250 psi at 385 gpm
  - Injection Zone TDS: 90,000 mg/L
- First Class I UIC General Discharge Permit issued by TCEQ for RO Concentrate Disposal

Concentrate Disposal Limitations

Concentrate disposal capacity limitations necessitated a strategy for management and disposal of water wasted during:

- Raw Water Wells at Startup
- Raw Water Pipeline Flushing at Startup
- Pretreatment System Flushing at Startup
- RO Skid Flushing at Startup and Shutdown

From Construction to Start-Up

Praveen Krishna, P. E.

Senior Engineer

ZACHRY PARSONS

Outline

- Project WQ Requirements
- WQ Sampling Plan Development
- Startup Planning & Data Collection
- Trend from Reliability Demonstration Testing (RDT)
- Commissioning Phase Data Collection
- Components Covered
  - Raw Water, Post Membrane Treatment, Finished Water, & Injection Wells

Key Requirements

- Why Sample
- What Parameters
- Requirements
  - TCEQ Regulatory
  - Operational Control
  - Performance Monitoring
  - Public Health - Safe Drinking Water

Project Finished Water Goals

Key Parameters

Turbidity

Iron

LSI

Parameter	Unit	Design Raw Water Quality[8]	Permeate Water Quality Goals[8]	TCEQ Drinking Water Standards	Finished Water Quality Goals[1]
Temperature	°C	25-35	NA	NA	28
	(°F)		NA	NA	82
Turbidity	NTU	1	NA	< 0.3	< 0.1
Total Dissolved Solids (TDS)	mg/L	1710[7]	<95	1000[2]	< 400
Calcium	mg/L	35	—	—	40 - 110
Magnesium	mg/L	17	—	—	NA
Hardness (Total)	mg/L as $CaCO_3$	160	—	—	100 - 300
Alkalinity	mg/L as $CaCO_3$	260	—	—	> 100
Sulfate	mg/L	560	<15	< 300[3]	10-75
Chloride	mg/L	270	<25	< 300[3]	< 100
Sodium	mg/L	470	<30	NA	NA
Strontium	mg/L	4.8	<0.1	NA	NA
Barium	mg/L	0.034	<0.1	NA	NA
Fluoride	mg/L	0.30	<0.1	NA	NA
Potassium	mg/L	9.5	<1.0	NA	NA
Silica	mg/L	21	<1.5	NA	NA
Color	Color Units	<10	—	< 15	< 3.0
Odor	T.O.N	<3	—	< 3	< 2.5
pH	—	7.6	—	> 7	7 - 8.5
Iron (Total)	mg/L	0.4	<0.1	< 0.3	< 0.2
Manganese (Total)	mg/L	0.06	—	< 0.05	< 0.03
Langlier Saturation Index (LSI)	—	NA	—	Depositing	0.1 - 0.4
Ryznar Stability Index (RSI)	—	NA	—	Depositing	< 8.0
Arsenic	mg/L	0.004	—	< 0.01	< 0.01
Hydrogen Sulfide	mg/L	<0.1	—	< 0.05	< 0.03
Radon	pCi/L	<300	—	< 300[4]	< 100
Radium-226 & 228, Combined	pCi/L	<5	—	< 5	< 3
Total Trihalomethanes (TTHM)	mg/L	NA	NA	< 0.08	< 0.04
Haloacetic Acids (HAA5)	mg/L	NA	NA	< 0.06	< 0.03

Startup: Planning

- Requirements
  - TCEQ – 30 TAC 290 Subchapter F – Rules, & Membrane Use Checklist.
  - Program Manager (B&V) Sampling Memo
  - Operational Requirements
  - Safety (Public Health)
- TCEQ Meeting
  - Present Sampling Plan, Identify Missing Information
- Plan for Startup, RDT, TCEQ Approval, SAWS Approval–
  - Present Plan to SAWS & PM
- Historical Data Management and Reports Workshop
  - Data Capture, Frequency, Storage,
  - Reports – Daily, Weekly, Monthly

Program Manager's Sampling Memo Excerpt (WQ)

Monitor
SDI
Iron
Conductivity

Table 2. Water Quality Monitoring to Consider for Process Understanding

Stream	Parameter	Freq	Discussion
Each Production Well	SDI	D, then W if stable	SDI is an important RO feed water parameter.
	Full (including Iron, Total & Dis)	W, then M – 6W	To develop understanding of each well.
	TDS	W, then M – 6W	To develop raw water site-specific ratio for TDS: Conductivity.
Combined Raw Water (pre-cart filt)	Same as for each production well: SDI, Full, and TDS	Same as each well	
RO Feed (post-cart filt)	SDI	D (possibly multiple/D during startup)	SDI is an important RO feed water parameter and most important at this location.
	Full (including Iron, Total & Dis)	M	
	Iron, total & dissolved	D, then W if stable	
Each RO unit	Conductivity map	1 time ~ 2 weeks after start, 1 M later, then every 6M	Measure conductivity (& enter data in a table) of every RO stream with a sample tap and perm from every vessel, as well as concurrently recording RO operating parameters and setpoints. This allows operators to find flaws in o-rings etc, and a useful historic data set for future comparisons and troubleshooting.

Startup: Planning

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Startup: Road Map

- Functional Testing and Startup Meeting
- Present Staffing, Operations, Sampling and Monitoring Plan for -
  - Coordination
  - Functional and Start Up Testing (2 Weeks)
  - Obtain TCEQ Approval
  - Reliability Demonstration Testing (30 Days)
  - Commissioning/Operations Phase (90 Days)
- Reporting and Monitoring Discussions

- TCEQ Compliance
- Process Monitoring
- Treatment Process Constraints

Startup: Experiences

- During Pre-Functional/Functional Testing
  - Irrigation Pond Operations and Limits
    - No Sewers Nearby
    - Permitted to Spray Irrigate 1,400 gpm at 2,000 mg/L TDS
    - Volume Limitation
    - Operating Duration
      (@ 5 mgd rate for 4 hrs; @ 2 mgd rate for 14 hrs etc.)
- Startup / RDT
  - Injection Wells
  - TCEQ Approval
- Finished Water Quality Goals were achieved

Startup: Sampling and Data Collection

REGULATORY MONITORING -			**PRODUCTION WELLS**										
			PW - 1	**- 2**	**- 3**	**- 4**	**- 5**	**- 6**	**- 7**	**- 8**	**- 9**	**- 10**	**- 11**	**- 12**
Monitoring	**Frequency**	**:. Location**	**Inst. ID**											
Level (Depth to wate	Continuous	PW	LT10	LT10	LT10	LT10	LT10	LT10	LT10	LT10	LT10	LT10	LT10	LT10
			Collected in SCADA. Can be printed as daily/monthly report											
Flow (gpm)	Continuous	Elec. Bldg.	FE10	FE10	FE10	FE10	FE10	FE10	FE10	FE10	FE10	FE10	FE10	FE10
			Collected in SCADA. Can be printed as daily/monthly report											
Pressure (psi)	Continuous	HMI	PIT/	PIT	PIT	PIT	PIT	PIT	PIT	PIT	PIT	PIT	PIT	PIT
			Collected in SCADA. Can be printed as daily/monthly report											
Turbidity (NTU)	Continuous	Elec. Bldg.	AE1	AE1	AE1	AE1	AE1	AE1	AE1	AE1	AE1	AE1	AE1	AE1
			Collected in SCADA. Can be printed as daily/monthly report											
WATER QUALITY FOR PERFORMANCE MONITORING - NON-REGULATORY														
SDI (field)	Weekly													
pH (field)	Weekly													
Alkalinity	Weekly													
Aluminum	Weekly													
Barium	Weekly													
Calcium	Weekly													
Chloride	Weekly													
Iron, Total	Weekly													
Iron, Dissolved	Weekly													
Magnesium	Weekly													
Silica	Weekly													
Sodium	Weekly													
Strontium	Weekly													
Sulfate	Weekly													
TDS	Weekly													
Ammonia	Weekly													
Fluoride	Weekly													
Manganese	Weekly													
Nitrate	Weekly													
Phosphate	Weekly													
Potassium	Weekly													
Calibration (Non-Reporting)		**Maintain Records For 3 Years.**												
	Required	**:. Location**	**W -**	**W -**	**W -**	**W -**	**W -**	**W -**	**W -**	**W -**	**W -**	**W -**	**W -**	**W -**
Level (Depth to water)		PW	LT10	LT10	LT10	LT10	LT10	LT10	LT10	LT10	LT10	LT10	LT10	LT10
TCEQ Required	Not Indicated	Date Calibrated												
Manufacturer Recom	Not Indicated	Date Calibrated												
Flow (gpm)		Elec. Bldg.	FE10	FE10	FE10	FE10	FE10	FE10	FE10	FE10	FE10	FE10	FE10	FE10
TCEQ Required	Once / 3 years	Date Calibrated												
Manufacturer Recom	Not Indicated	Date Calibrated												
Pressure (psi)		HMI	PIT/	PIT	PIT	PIT	PIT	PIT	PIT	PIT	PIT	PIT	PIT	PIT
TCEQ Required	Annually	Date Calibrated												
Manufacturer Recom	Calc. Using Ma	Date Calibrated												
Turbidity (NTU)		Elec. Bldg.	AE1	AE1	AE1	AE1	AE1	AE1	AE1	AE1	AE1	AE1	AE1	AE1
TCEQ Required	Quarterly	Date Calibrated												
Manufacturer Recom	Quarterly	Date Calibrated												

- Production Wells
- Combined Raw Water
- RO Feed
- Total Permeate
  - Skids 1 through 4
  - 2 Concentrators
- Combined RO Permeate
- Combined RO Concentrate
- Calcite Contactors
  - Individual & Combined Effluent
- Degasifier
- Chlorine Contact Tank
- Finished Water
- Injection Wells &
- Chemicals

Startup: WQ Data

WQ MONITORING REQUIREMENTS BASED ON MEMBANE USE CHECKLIST - USED TO OBTAIN TCEQ APPROVALS

Parameter	Units		USEPA / Standard Methods Test Method	Combined Raw Water before Chemical Addition 18 Oct 2016 (18-Oct-16)	Combined Permeate 18 Oct 2016 (18-Oct-16)	Finished Water 18 Oct 2016 (18-Oct-16)
Maximum Contaminant Level (MCL)		MCL				
Nitrate	mg/l as N	10	300	ND	ND	ND
Nitrite	mg/l as N	1	300	ND	ND	ND
Arsenic	micro g/l	10	200.8	ND	ND	ND
Fluoride	mg/l	4	SM4500F-C	0.22	ND	ND
Secondary Contaminant Level (SCL)		SCL				
Aluminum	mg/l	0.2	200.8	ND	ND	ND
Copper	mg/l	1	200.8	ND	ND	ND
Lead (Action Level)	mg/l	0.015	200.8	ND	ND	ND
Iron	mg/l	0.3	200.7	0.23	ND	ND
Manganese	mg/l	0.05	200.8	58	ND	ND
Zinc	mg/l	5	200.8	ND	ND	ND
Total Dissolved Solids	mg/l	1000	160.1	1200	33	86
Fluoride	mg/l	2	SM4500F-C	0.22	ND	ND
Sulfate	mg/l	300	300	480	9.3	2.9
Chloride	mg/l	300	300	240	2	10
pH		>= 7	SM4500-HB	8.1	6.5	9.6
Corrosive Water Parameters						
Alkalinity	mg/l		SM 2320B	210	12	40
Calcium	mg/l		200.7	34	ND	5.8
Sodium	mg/l		200.7	370	13	21
Radiological Analyses (MCL)		MCL				
Gross alpha	pCi/L	15	900	1.3	3.2	ND
Radium 226	pCi/L	5	900	ND	ND	ND
Radium 228	pCi/L	5	904	ND	ND	ND
Beta particle	pCi/L	50	900	6.7	ND	ND
Uranium	micro g/L	30	200.8	ND	ND	ND

RDT: Experiences

- Reliability Demonstration Testing was Required to Demonstrate the Plant Operated as Designed and Intended.
- Testing Duration – 30 Days of Continuous Operation
- Water Quality Data Collection
  - Safety (Public Health)
  - Operation & Performance Monitoring

RDT: Trends

Key Trends-

- Flow
- Recovery
- Conductivity
- Diff. Pressure

Commissioning: Experiences

- Commissioning Phase (90 Day Duration)
  - Routine was Established
  - TCEQ Monthly Operating Reports
  - Process Monitoring Reports
  - SCADA Reports
  - Zachry Parsons Operators and Staff
  - Training SAWS Operators Simultaneously

Commissioning: TCEQ Reporting

Sample Form

Injection Well Monitoring Report

TEXAS COMMISSION ON ENVIRONMENTAL QUALITY
6300 Ocean Drive ☐ Suite 1200 ☐ Corpus Christi, Texas 78412
QUARTERLY INJECTION REPORT

San Antonio Water System Brackish Groundwater Desalination Project
4588 Hardy Road
Elmendorf, TX 78112
Attn: Mr. Kevin Morrison

Report for WDWG010001 Quarter 1, 201X

Parameter (Permit Limit)	January (1)	No. Exc.	February (2)	No. Exc.	March (3)	No. Exc
Hours Operated Per Month						
Average Flow Rate (No permitted limit)						
Total Volume Per Month (24.33 MGM)						
Total Volume For Year (292.0 MG)						
Total Volume Per Month For Facility (121.67 MGM)						
Total Volume Per Year For Facility (1460.0 MG)						
Injection Rate Max. (1000 GPM instantaneous)						
Facility Monthly Injection Rate Ave. (500 GPM)						
Injection Pressure Maximum (775 PSI)						
Annulus Differential Pressure, Minimum (100 PSI)						
pH Minimum (>7.0)						
pH Maximum (<7.5)						
Specific Gravity Maximum (1.02 @ 60°F)						

I CERTIFY THAT I AM FAMILIAR WITH THE INFORMATION CONTAINED IN THIS REPORT AND THAT TO THE BEST OF MY KNOWLEDGE AND BELIEF SUCH INFORMATION IS TRUE AND COMPLETE AND ACCURATE.	SEE BOTTOM OF PAGE 1 FOR ABBREVIATIONS AND DEFINITIONS

TELEPHONE NO.	COMPANY REPRESENTATIVE		DATE		
	PRINT NAME	SIGNATURE	MONTH	DAY	YEAR

San Antonio Water System
25 WATERFUL YEARS

Operations, Performance, and Growth

Roberto Macias

Manager, Production and Treatment Operations, SAWS

Operational Challenges

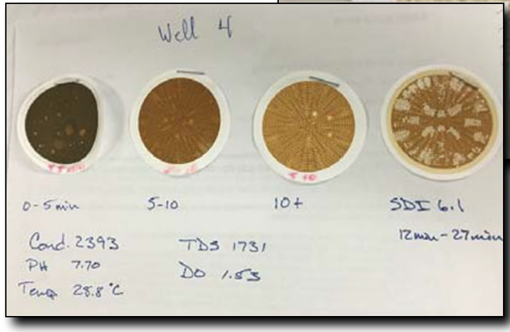
Silica and Iron

- Due to higher design recovery, both Iron and Silica were concerns from initial well data
- More than 50% of iron is maintained in dissolved form
- Cause of partial iron oxidation (measured at well) is uncertain
  - Low amounts of DO are present in raw water at the wellhead
  - ORP is consistently negative (-150 to -200 mV)
  - No clear correlation between oxidized iron, DO, and ORP
- Well operational pre-flushing is necessary
- Well pump speed control philosophy has proved to provide stable and reliable control
- Raw water entering the WTP maintains a negative ORP

Operational Challenges

SDI (Silt Density Index)

- Overall raw water quality (SDI and turbidity) appears to be improving over time, however:
  - Some wells continue to produce higher turbidity and SDI despite redevelopment flushing
  - A few wells have been observed to "burp up" turbidity from time to time
- SAWS is continuing to monitor supply well quality
  - Suspended: Rossum sand tests, SDI, and Turbidity
  - Dissolved oxygen, ORP, and dissolved and total iron



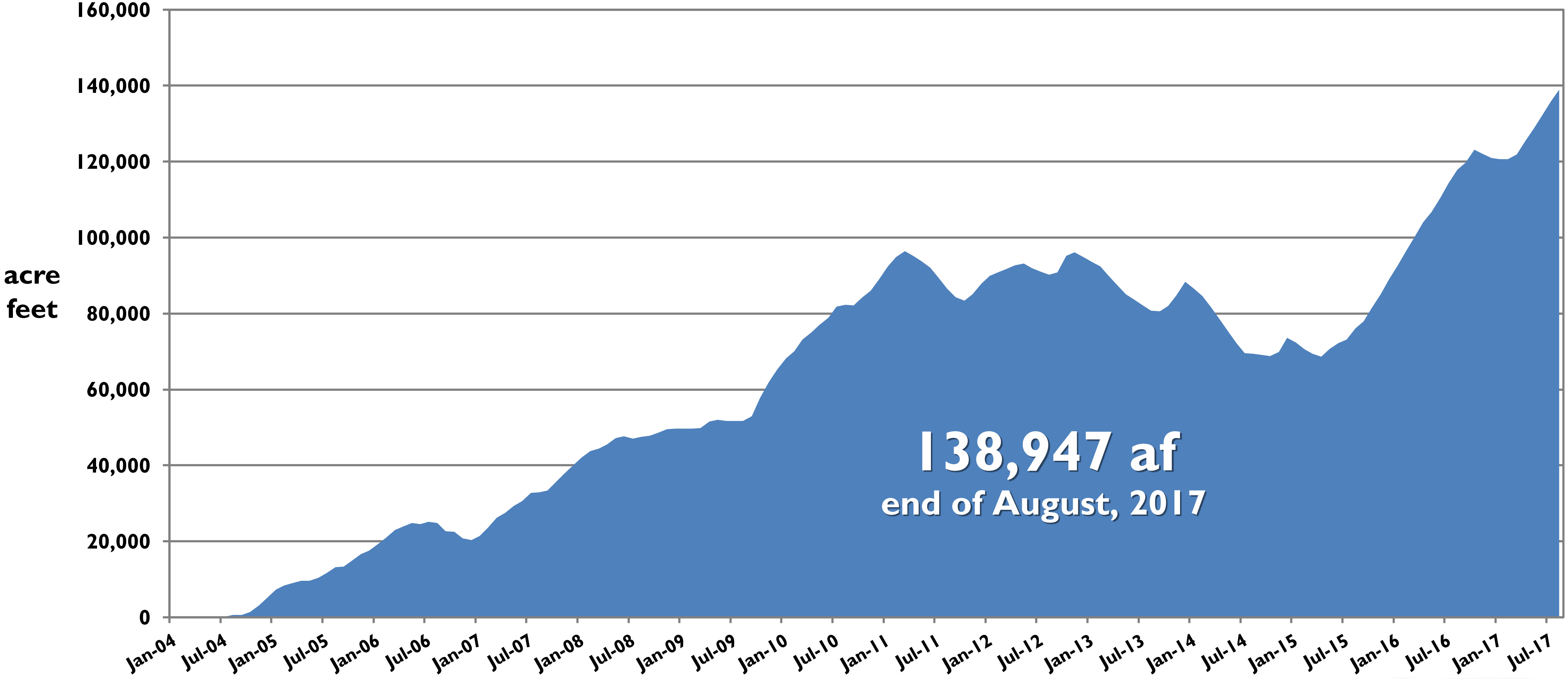
Operational Challenges

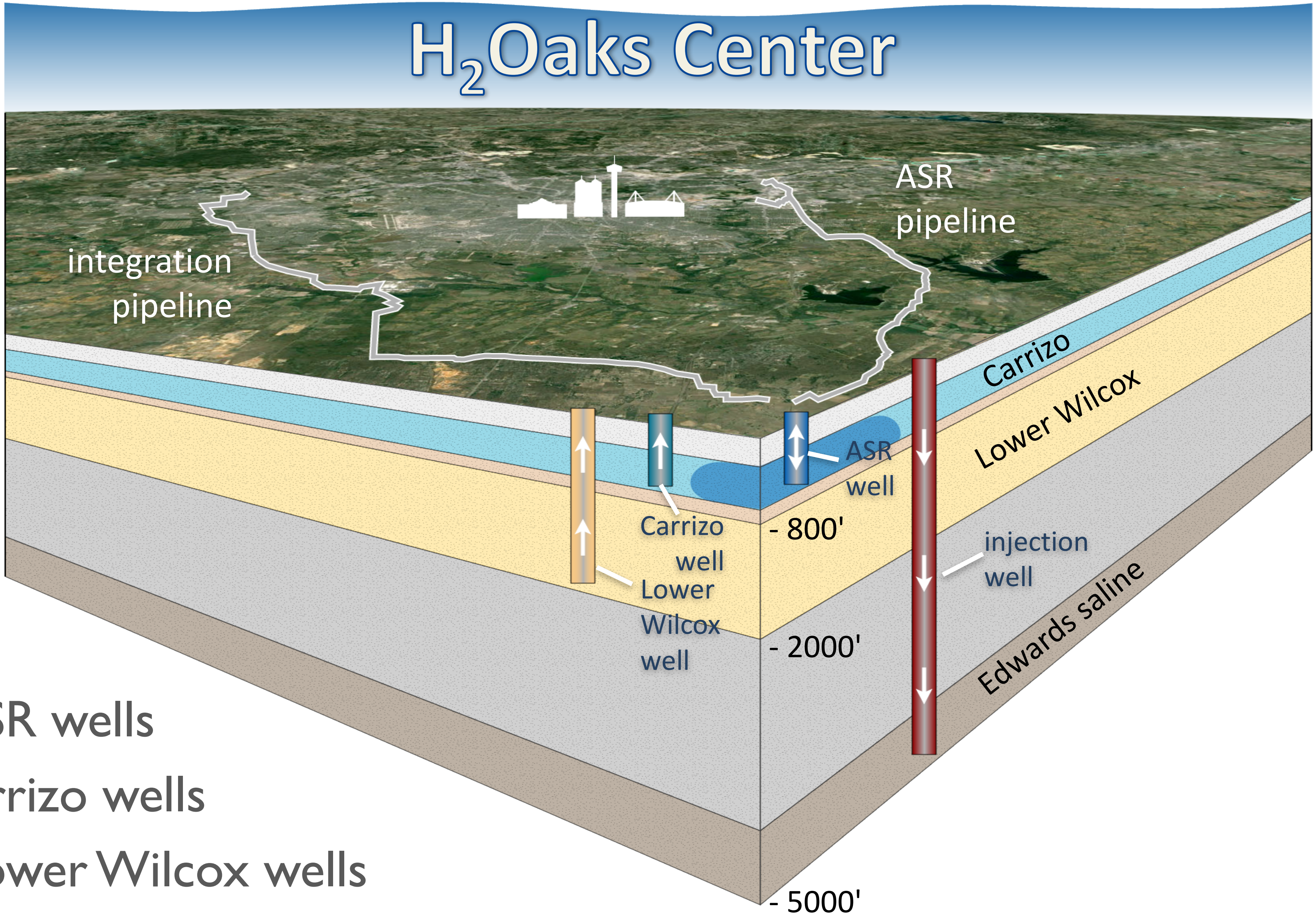
- Improper Well and Raw Conveyance Flushing
  - Well flushing timers were reduced to expedite I&C functional testing (prior to membrane loading) resulted in high SDI and rapid fouling of cartridge filters at WTP
  - Suspended solids would quickly settle out in the conveyance pipeline if pre-flush was not performed, later to be pushed into the WTP at higher operating flows
- Design considerations of pre-flush at each well have proven to be a good preventive measure
- Design included permanent features to flush raw conveyance pipelines
- Water quality becomes stable at steady state conditions

Carrizo Aquifer Treatment Facility

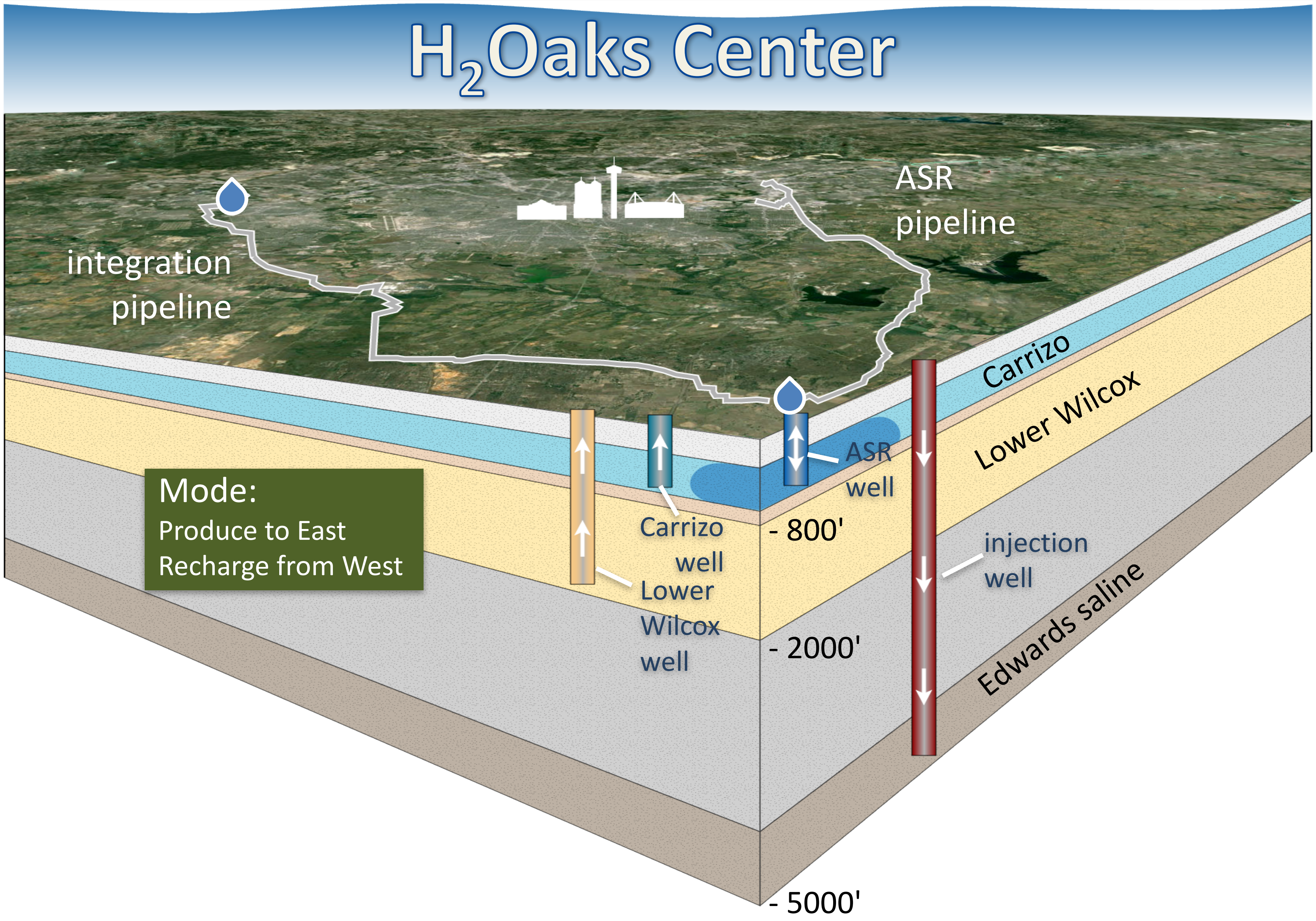

Water in Storage

Water In Storage



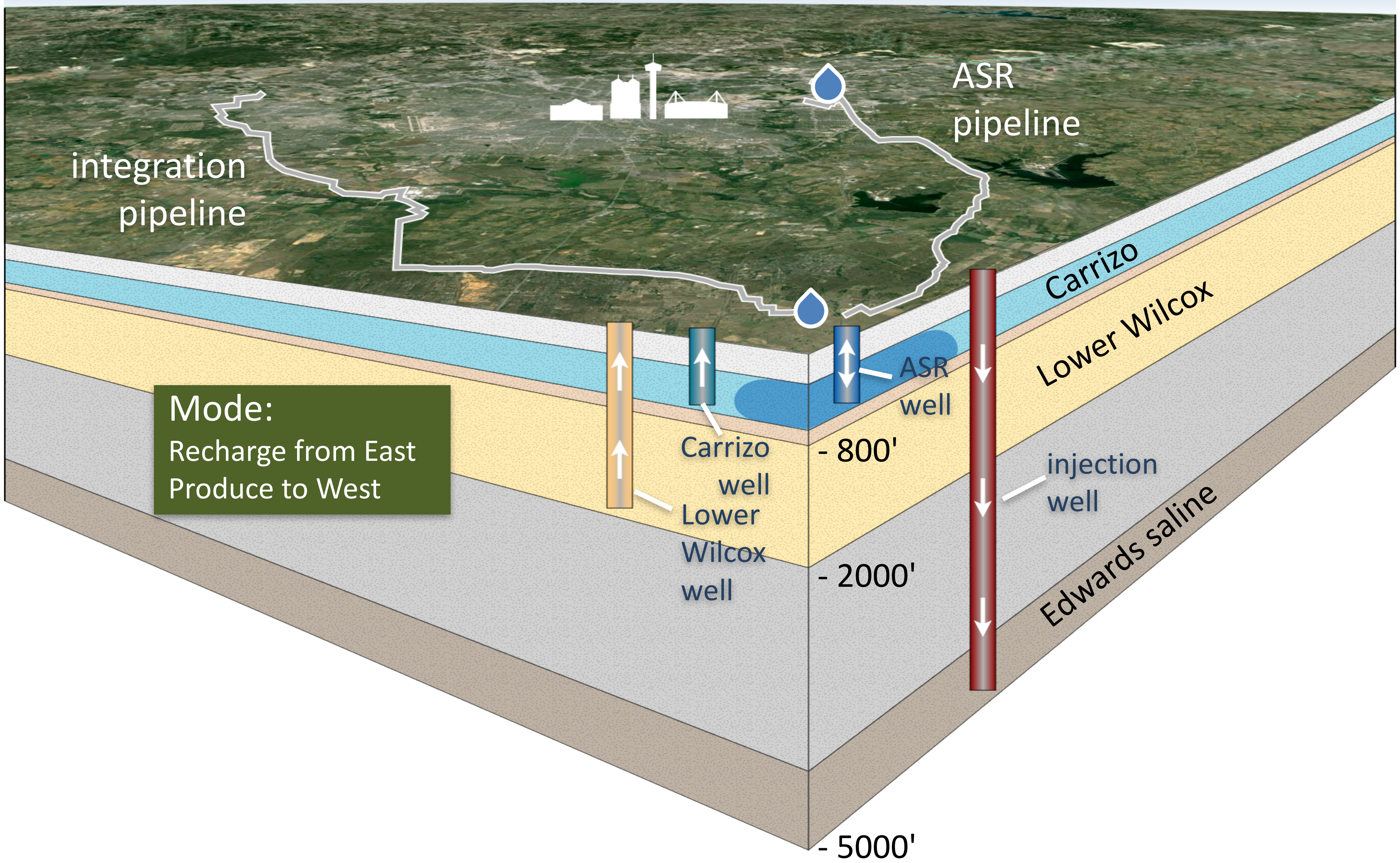


- 29 ASR wells
- 7 Carrizo wells
- 11 Lower Wilcox wells

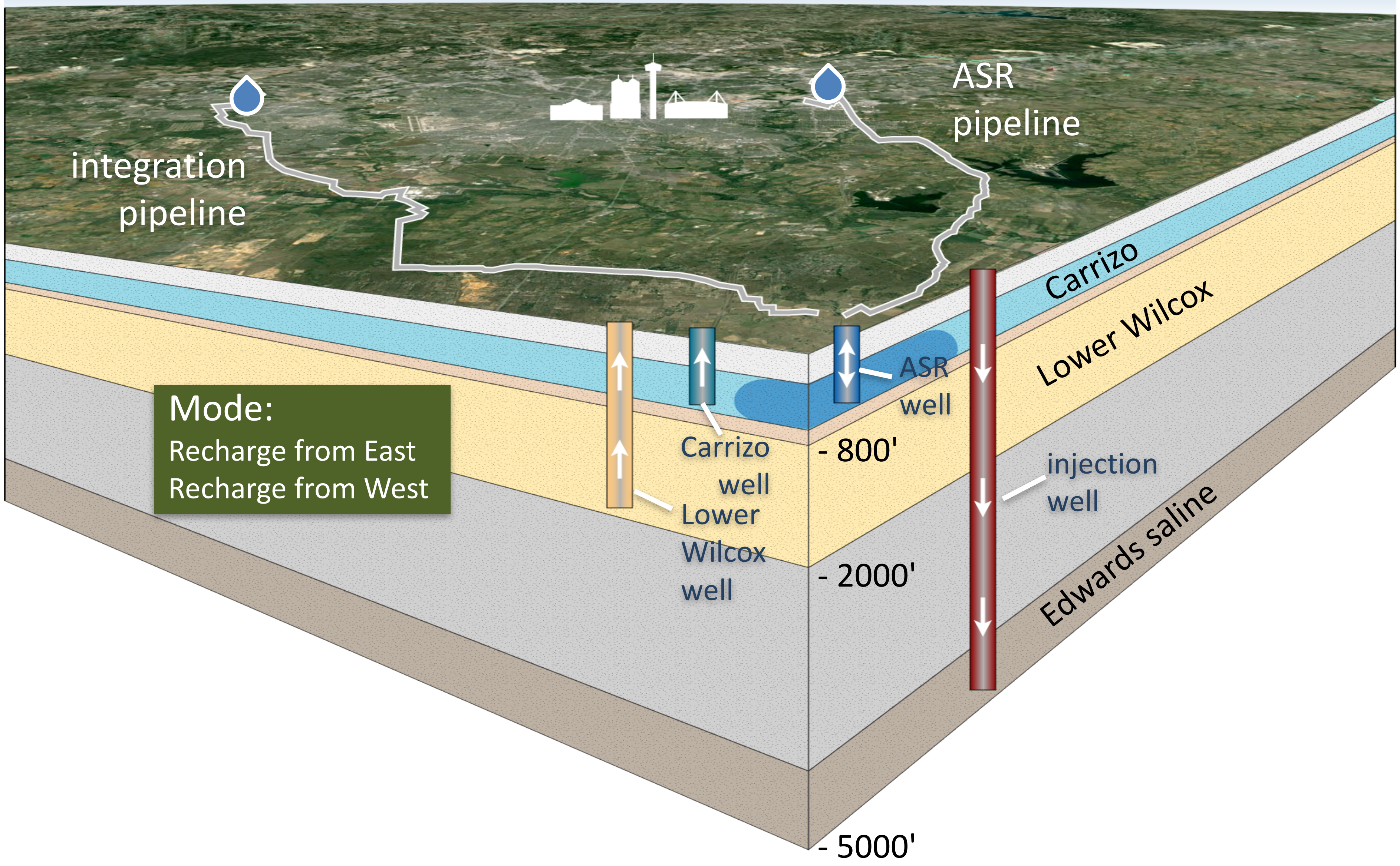


H₂Oaks Center
ASR
pipeline
integration
pipeline
Carrizo
Lower Wilcox
Edwards saline
Mode:
Produce to East
Recharge from West
ASR
well
Carrizo
well
Lower
Wilcox
well
injection
well
- 800'
- 2000'
- 5000'

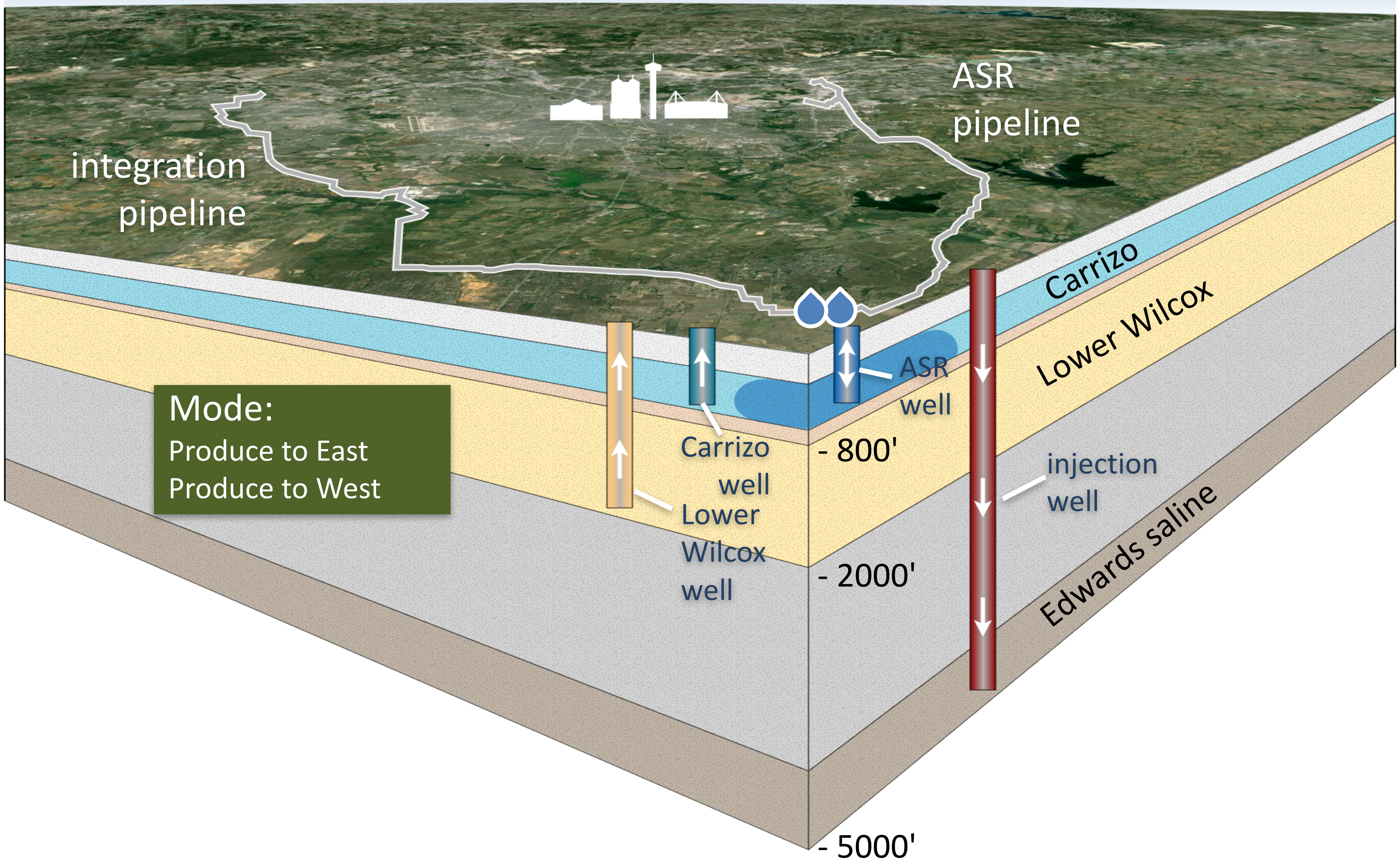
H_2Oaks Center



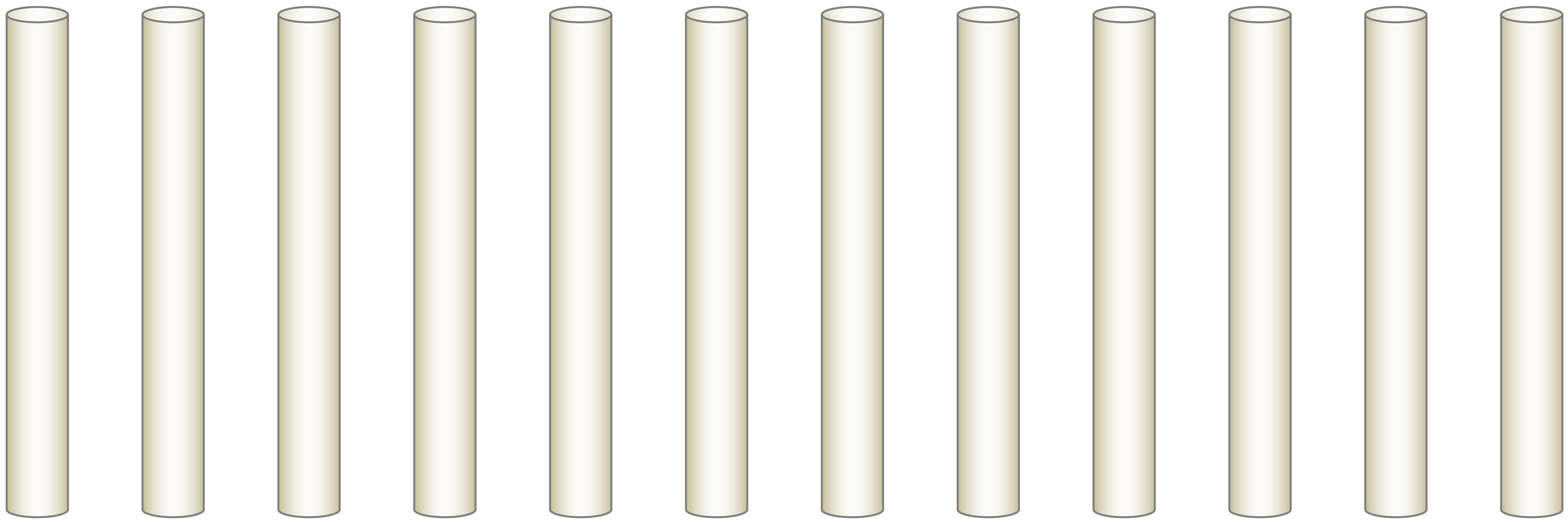
H_2Oaks Center



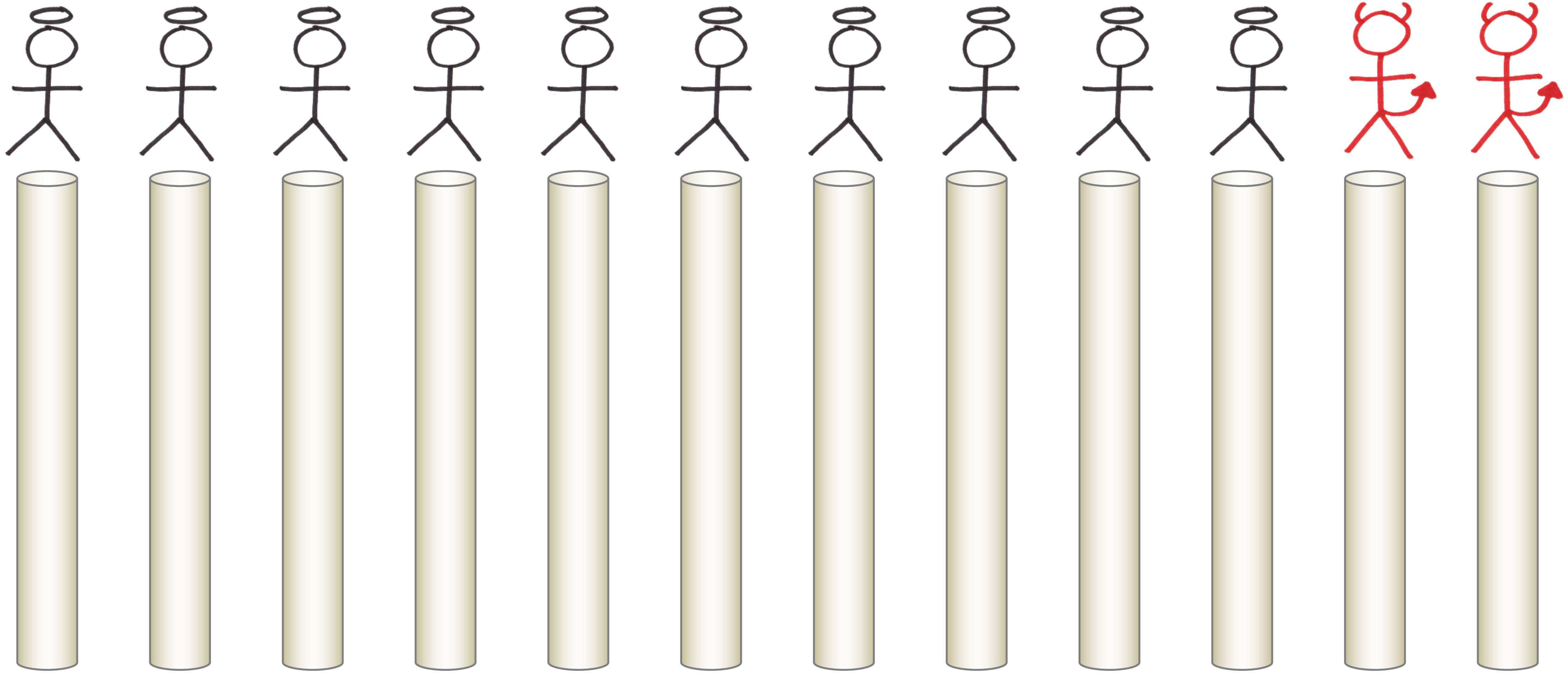
H_2Oaks Center



12 Wells: It's Like 12 Children



12 Wells: It's Like 12 Children



Questions?

The SAWS Story: Developing Brackish Desal in Texas

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SAWS
San Antonio Water System
WATERFUL YEARS

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September 20, 2017

MAKING SAN ANTONIO
WATERFUL