Natural Storage

Innovative Methods to Store Water

Collier County Comprehensive Watershed Improvement Program Committee

Wednesday, December 14, 2016

Opportunities…

Every challenge presents an opportunity

- ✓ Stormwater retention
- ✓ Value of water
- ✓ Cost (life cycle)
- ✓ Water quality…for intended purpose
- ✓ Optimization of water use

The Facts about ASR in Florida

FSAWWA

90th

Gala Celebration

ANNIVERSARY 2016 FALL CONFERENCE

The Value of Water

Hazen

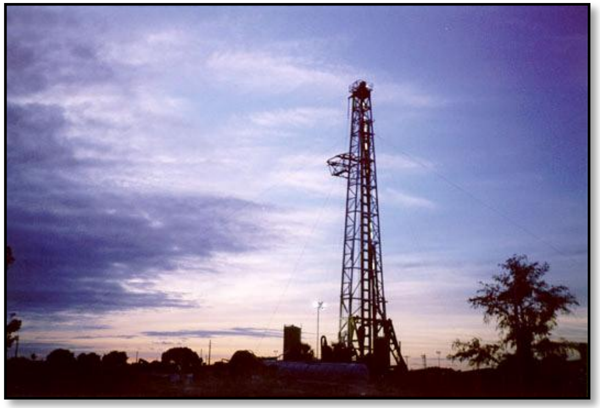
90th Anniversary 2016 Fall Conference – THE VALUE OF WATER

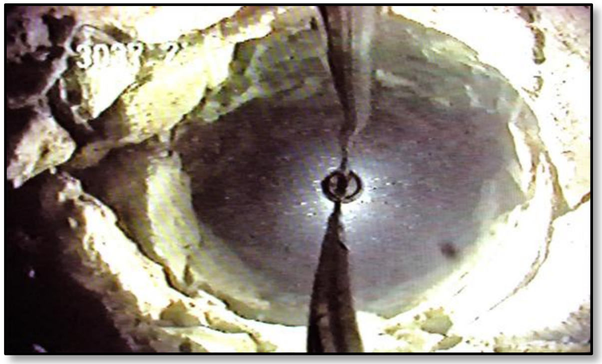
“The Facts about Aquifer Storage and Recovery in Florida"

November 27 – December 1, 2016 Orlando, FL

Presentation outline

- Background
- Overview of ASR
- Benefits and Hurdles
- Conclusions
- The Future

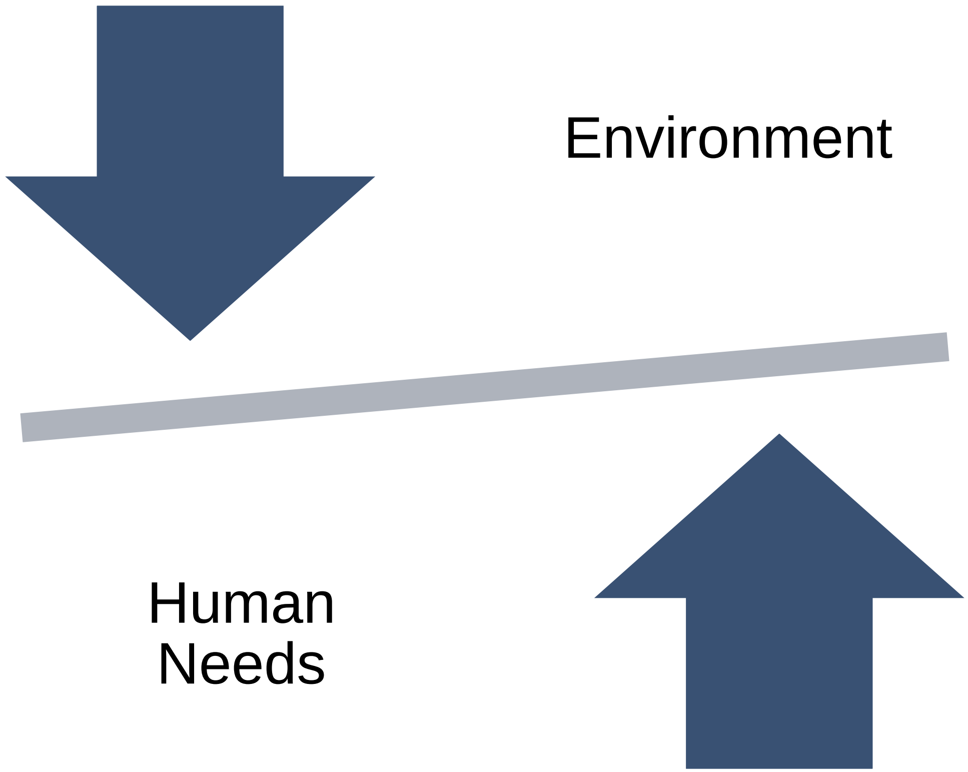




Background

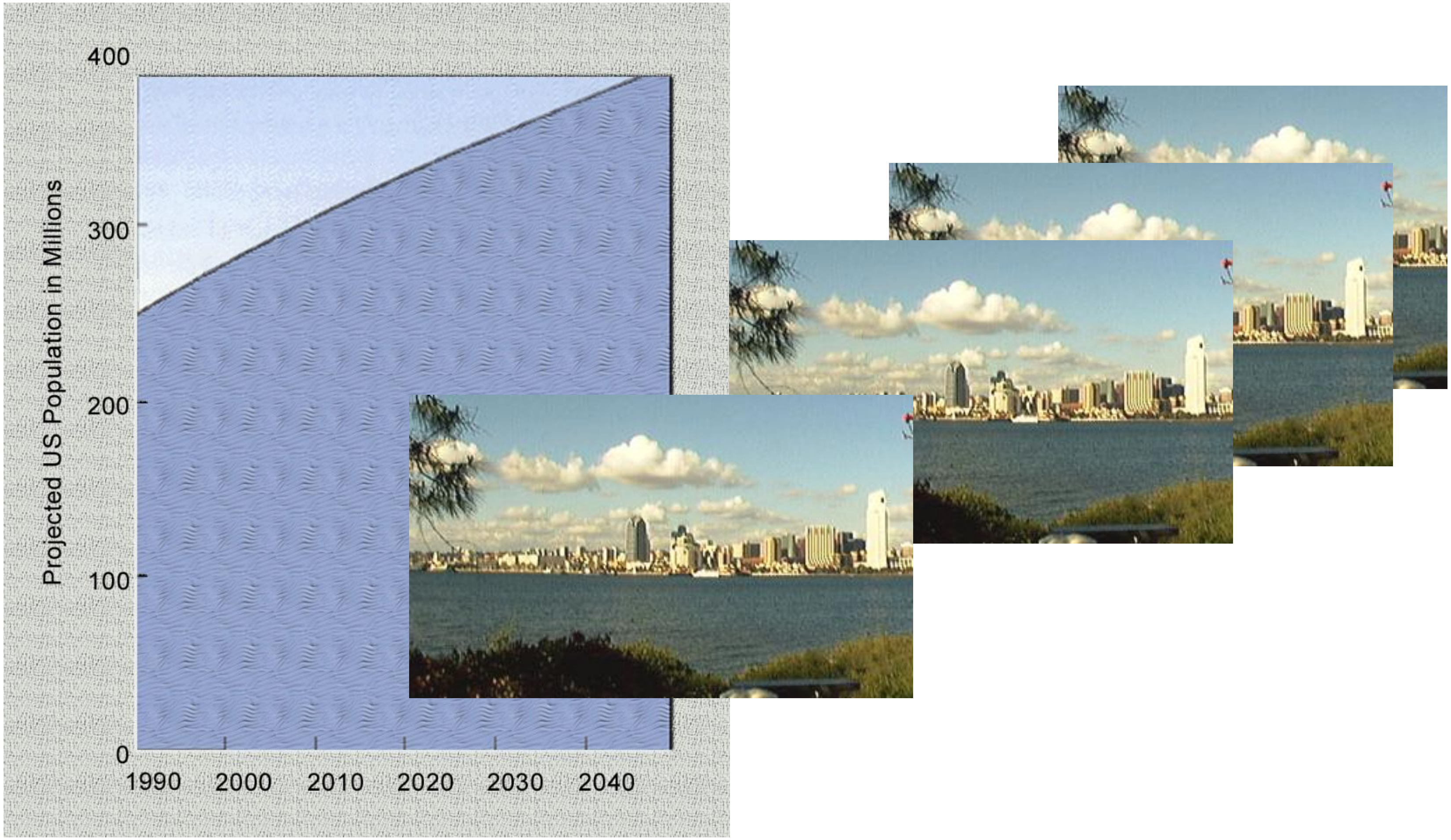
Water availability is vital to provide both quantity and quality that is acceptable for demands

How to balance objectives that may be in conflict

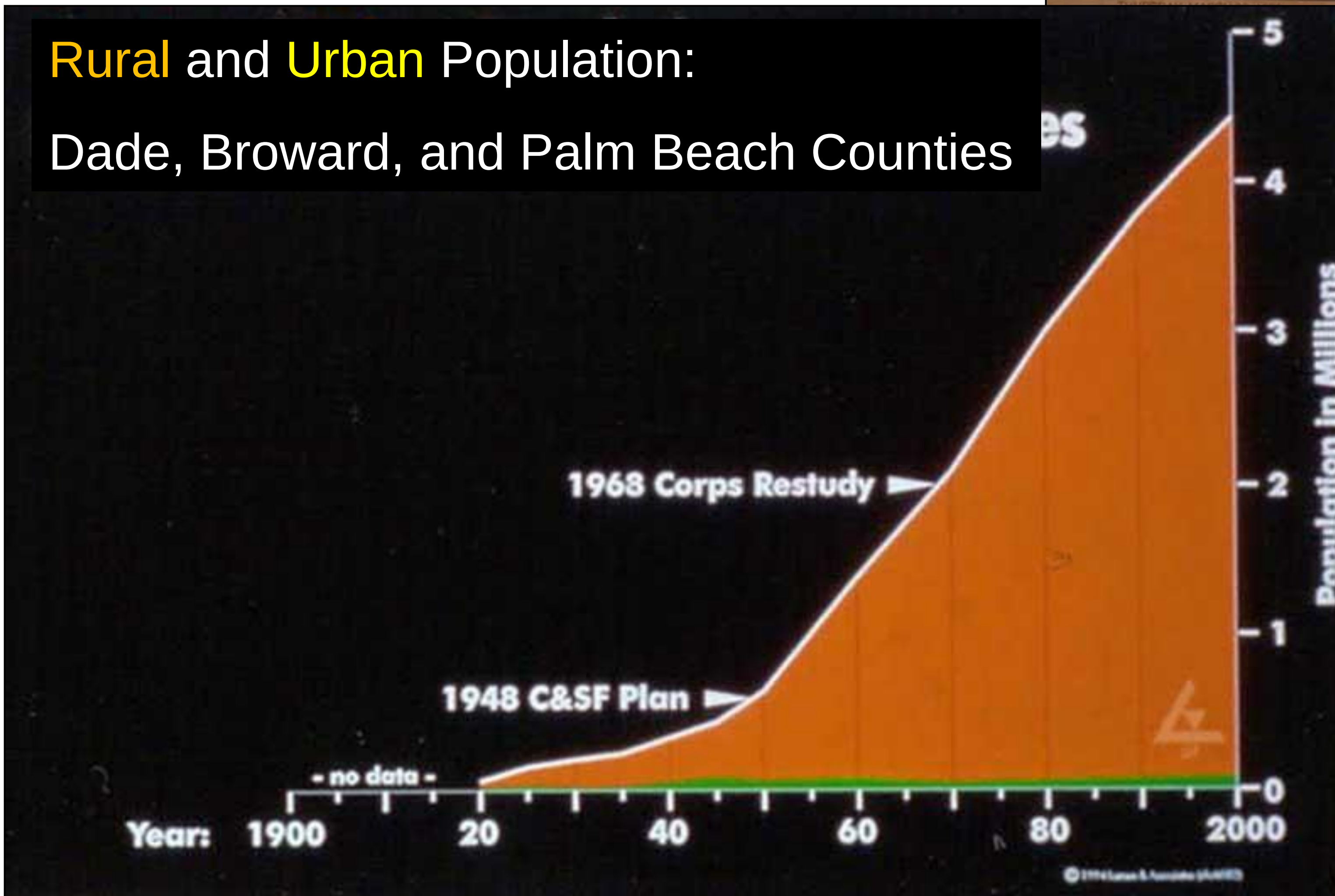


Environmental protection is paramount

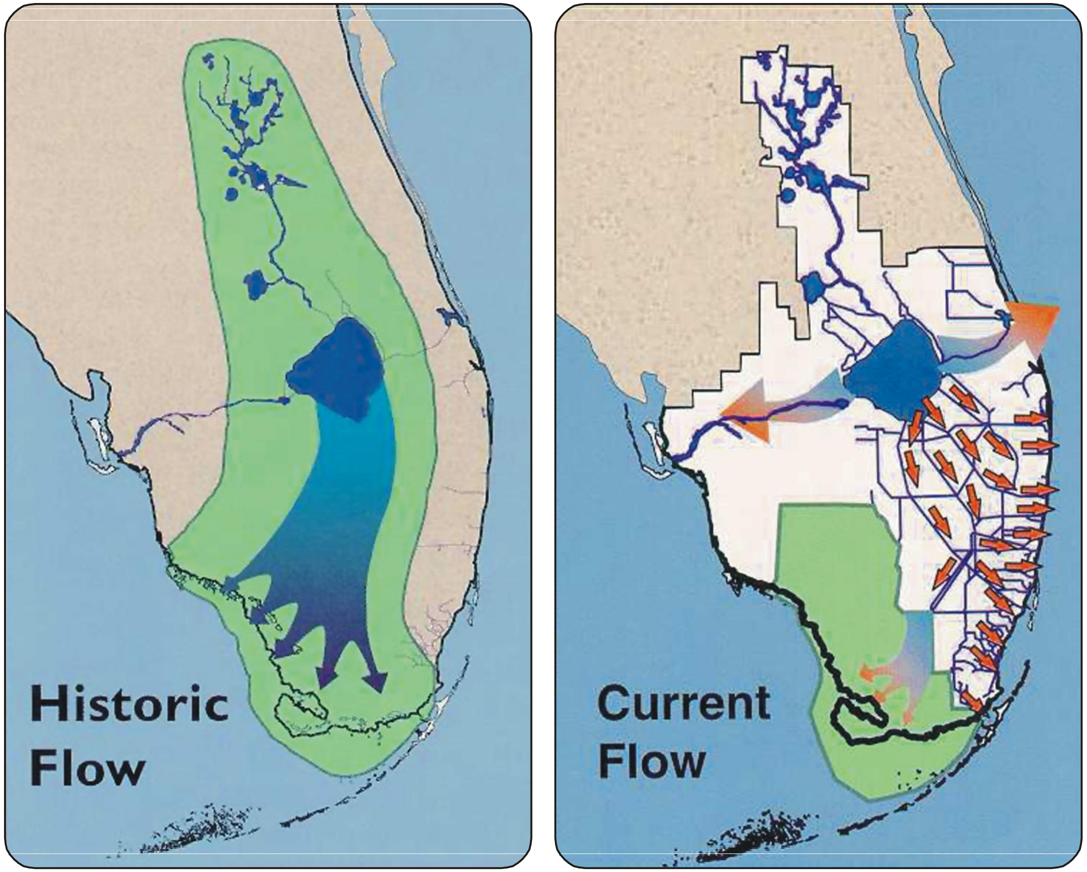
…but growth is coming so how do we plan?



Growth stresses existing resources

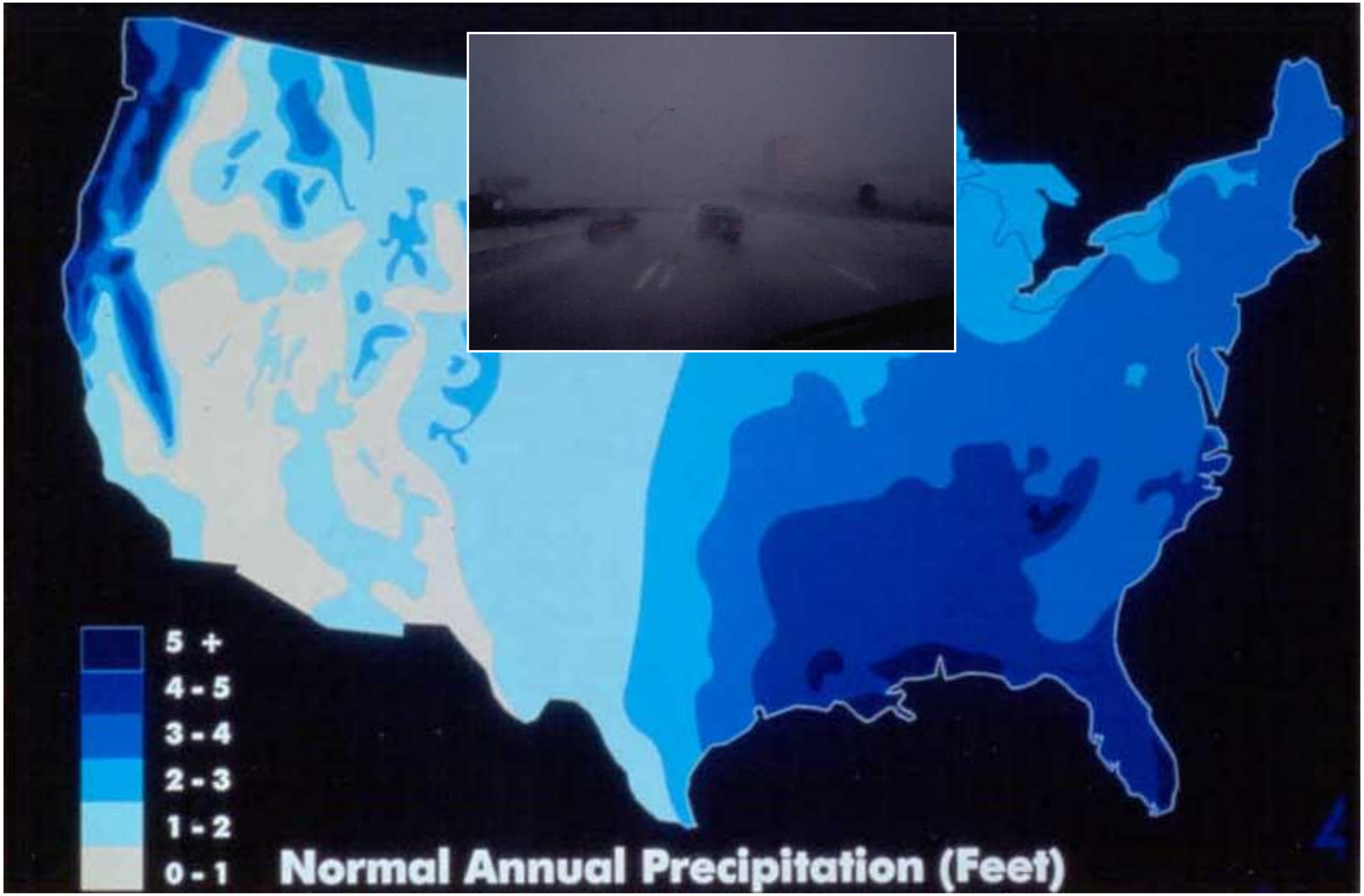


Much of the United States is water limited, but not the case in south Florida



1.7 billion gpd once available to ecosystem discharged

Florida has excessive rainfall when it's least needed



Water management

Prudent water management is essential for sustainability, and must address both environmental protection and human survival

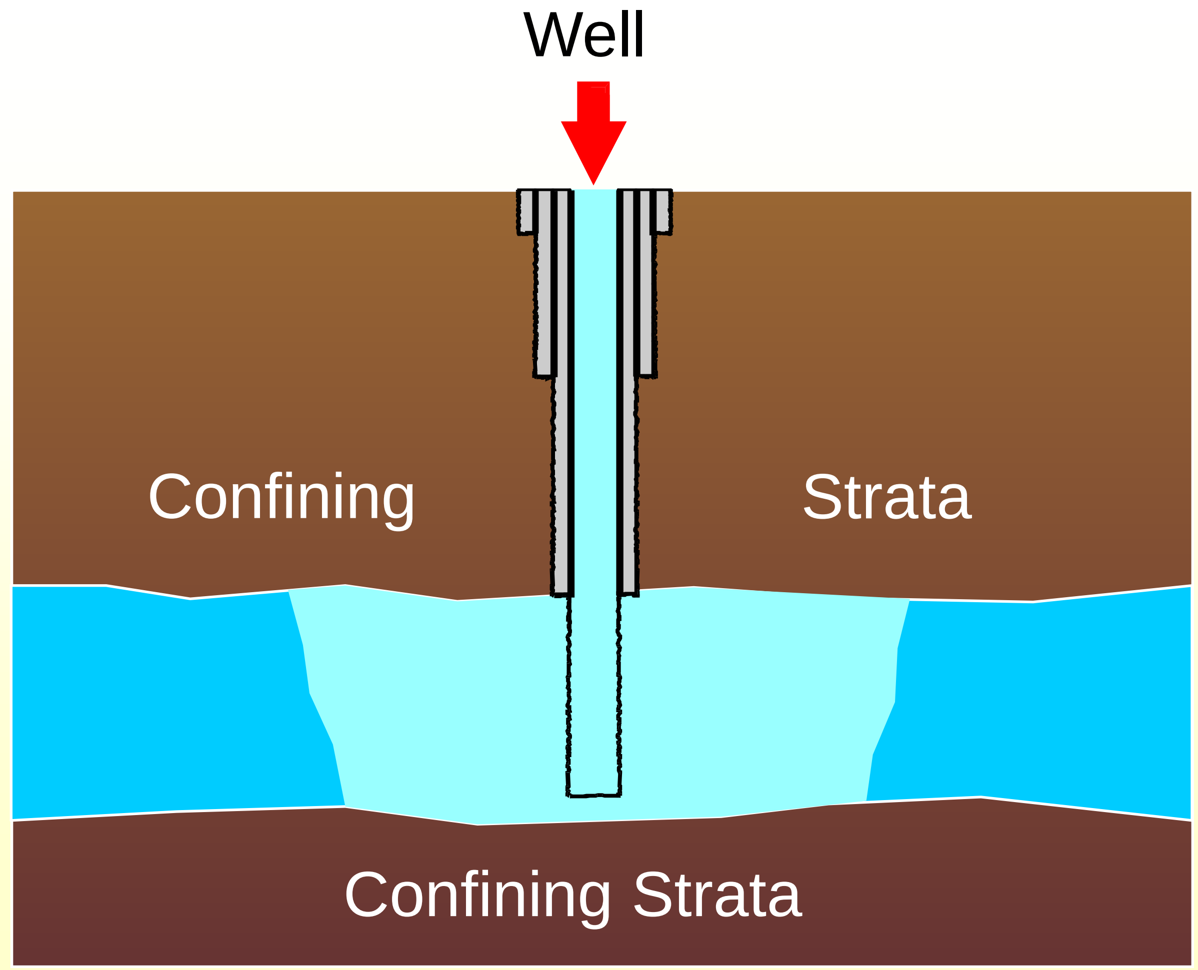
Aquifer Storage and Recovery tool

Underground storage

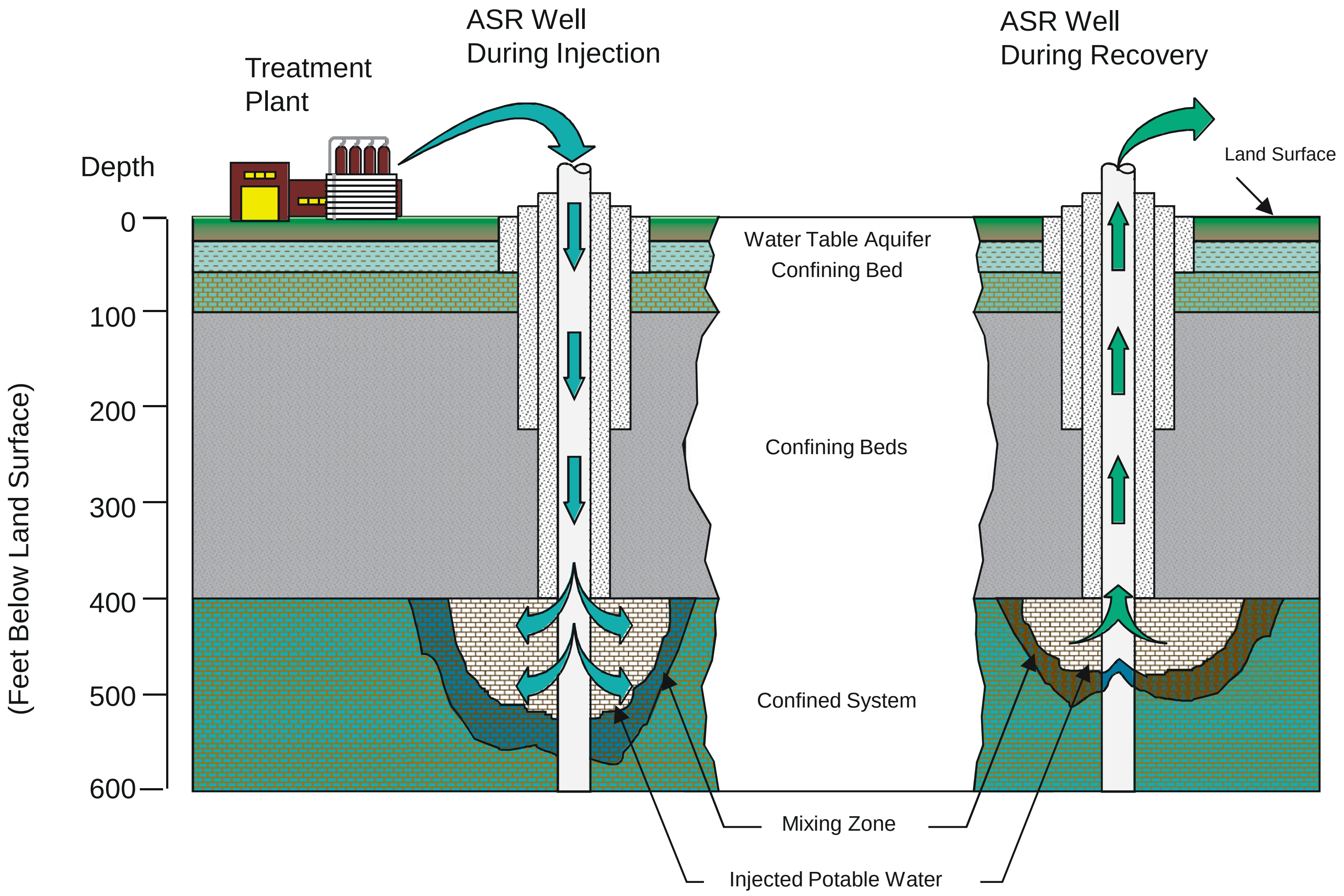
Basic definition of the ASR concept

Aquifer storage and recovery, also known as ASR, is the underground storage of excess water in a suitable underground horizon, and recovery of stored water to meet a specific demand(s)

The "bubble factor"



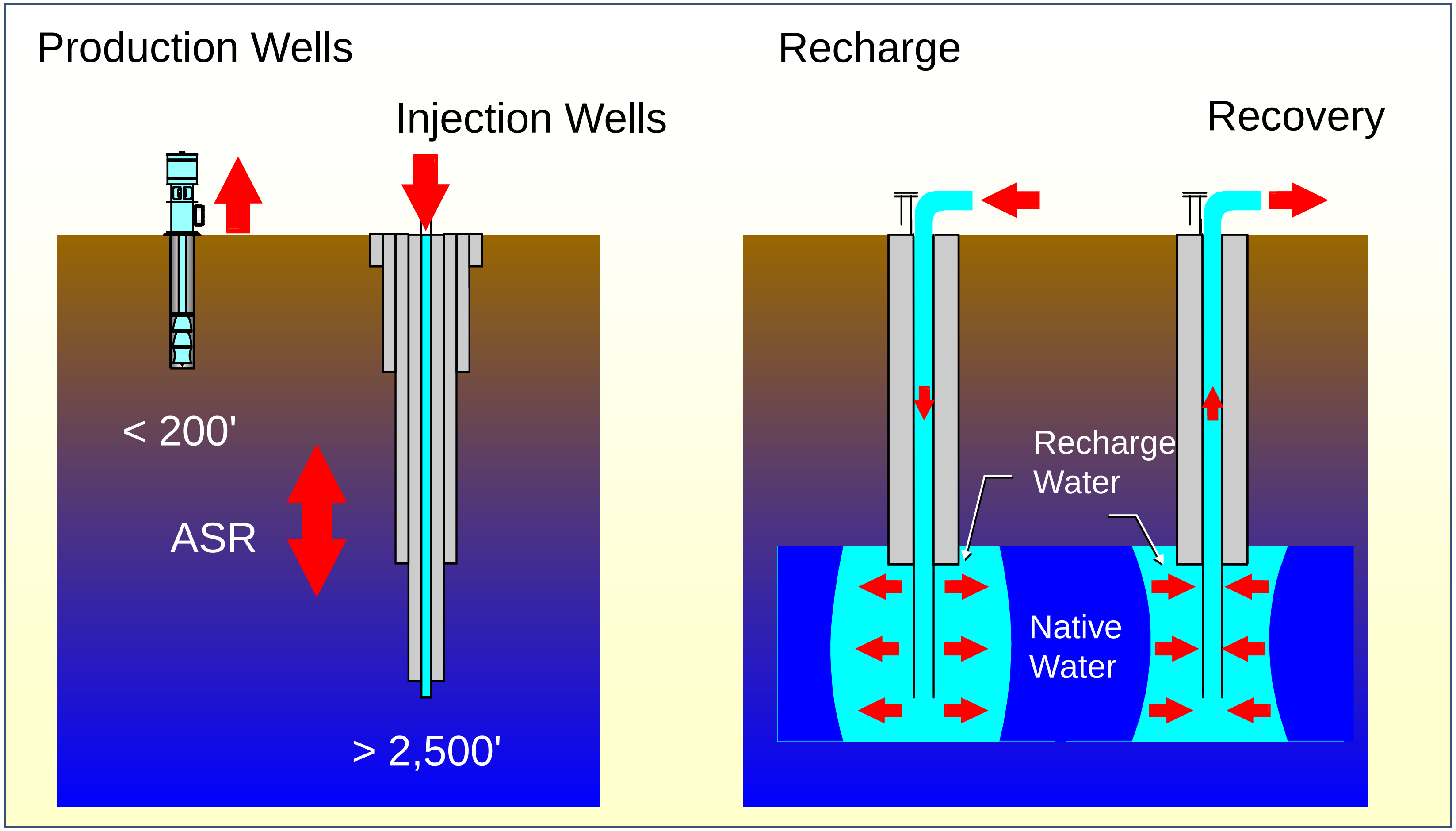
Aquifer Storage and Recovery – Conceptual diagram



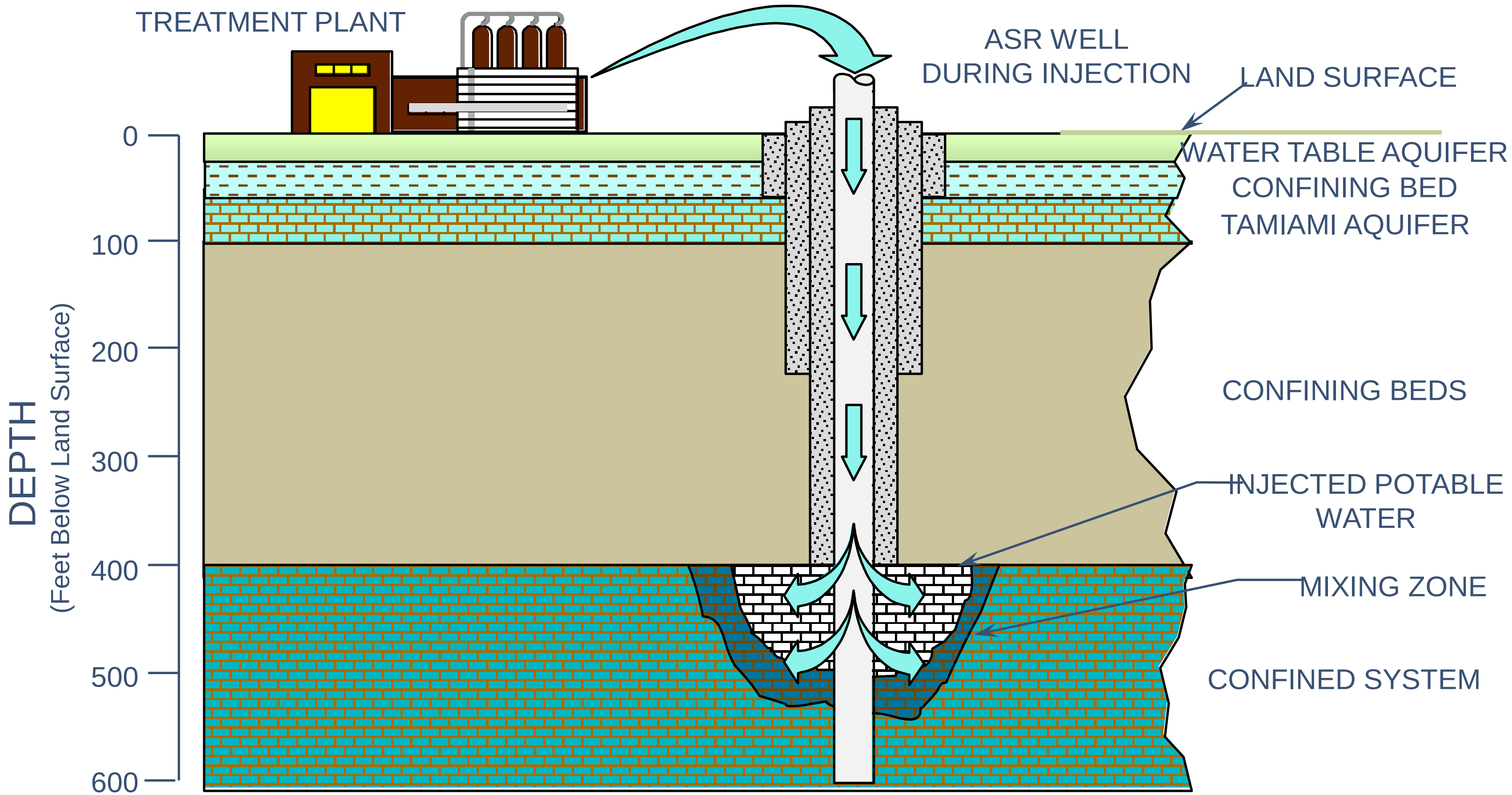
Design of ASR wells

- ASR wells are hybrid wells; part injection well, part storage well, and part production well
- Regulations concerning construction, testing, withdrawal and storage impact multiple agencies
- Water quality of native zone, injected fluids and final use are critical
- Injection rate, storage period and recovery rates are also key design elements

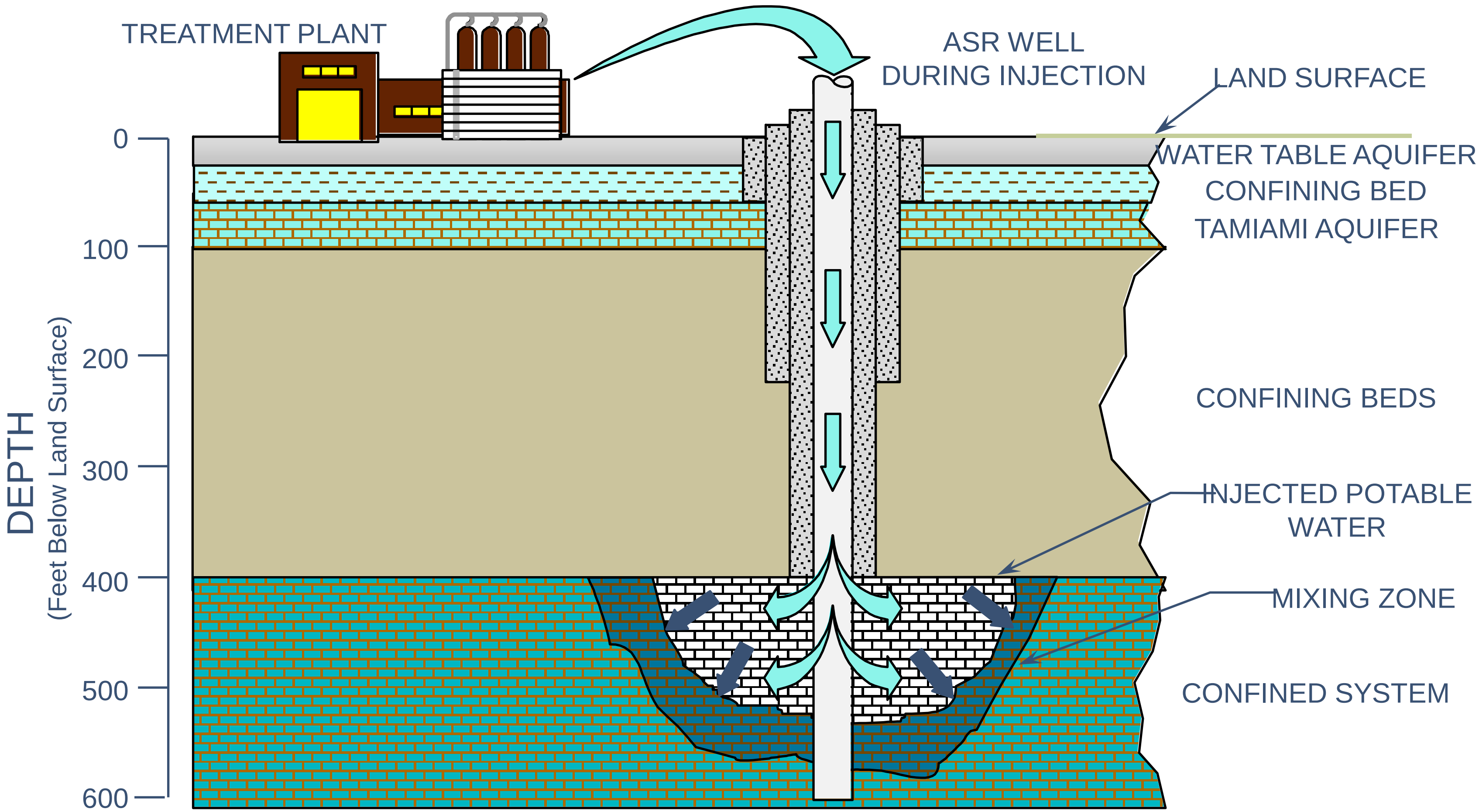
ASR systems are unique…testing and final design must address site specific conditions



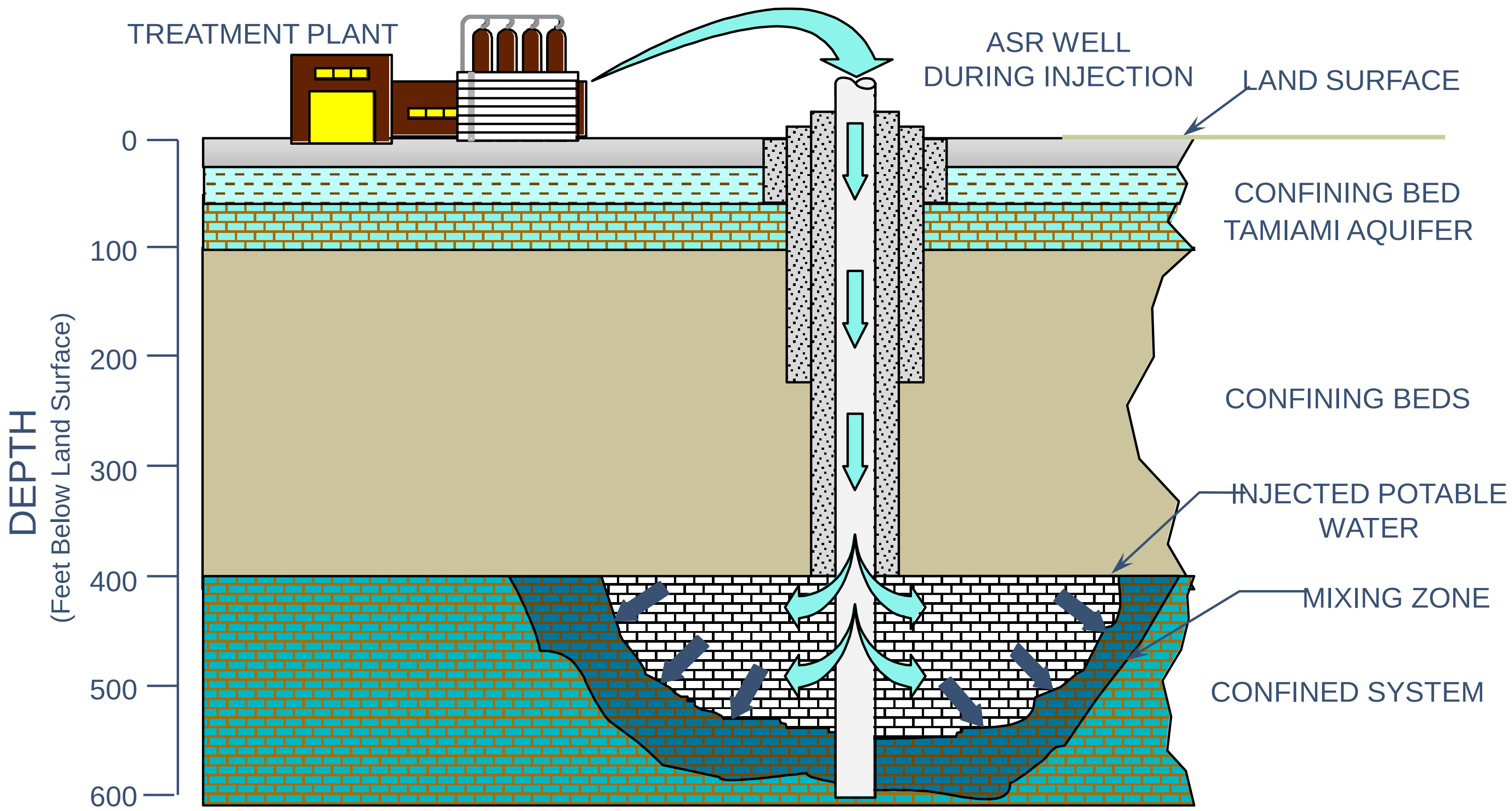
Conceptual diagram



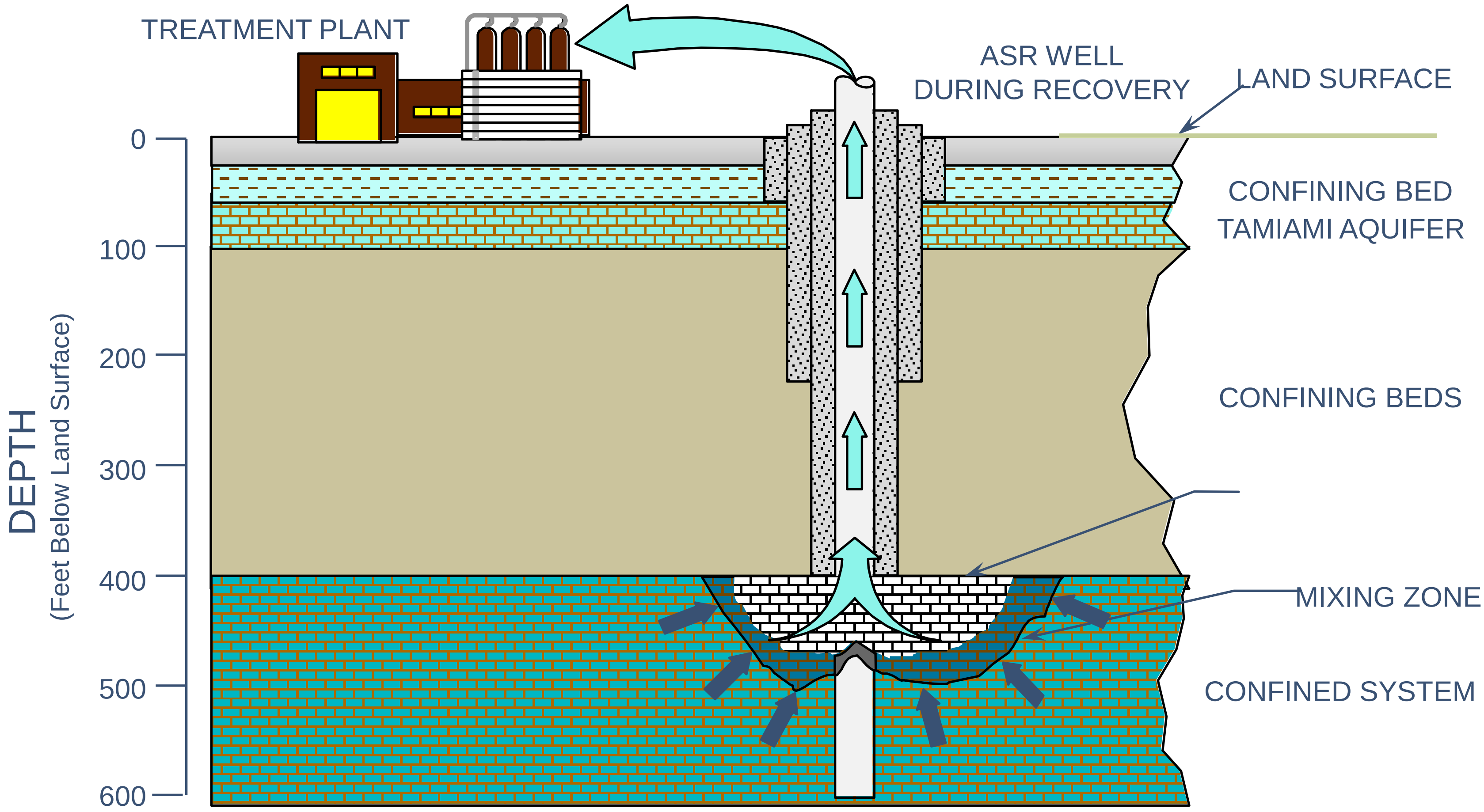
Store excess water when water is available



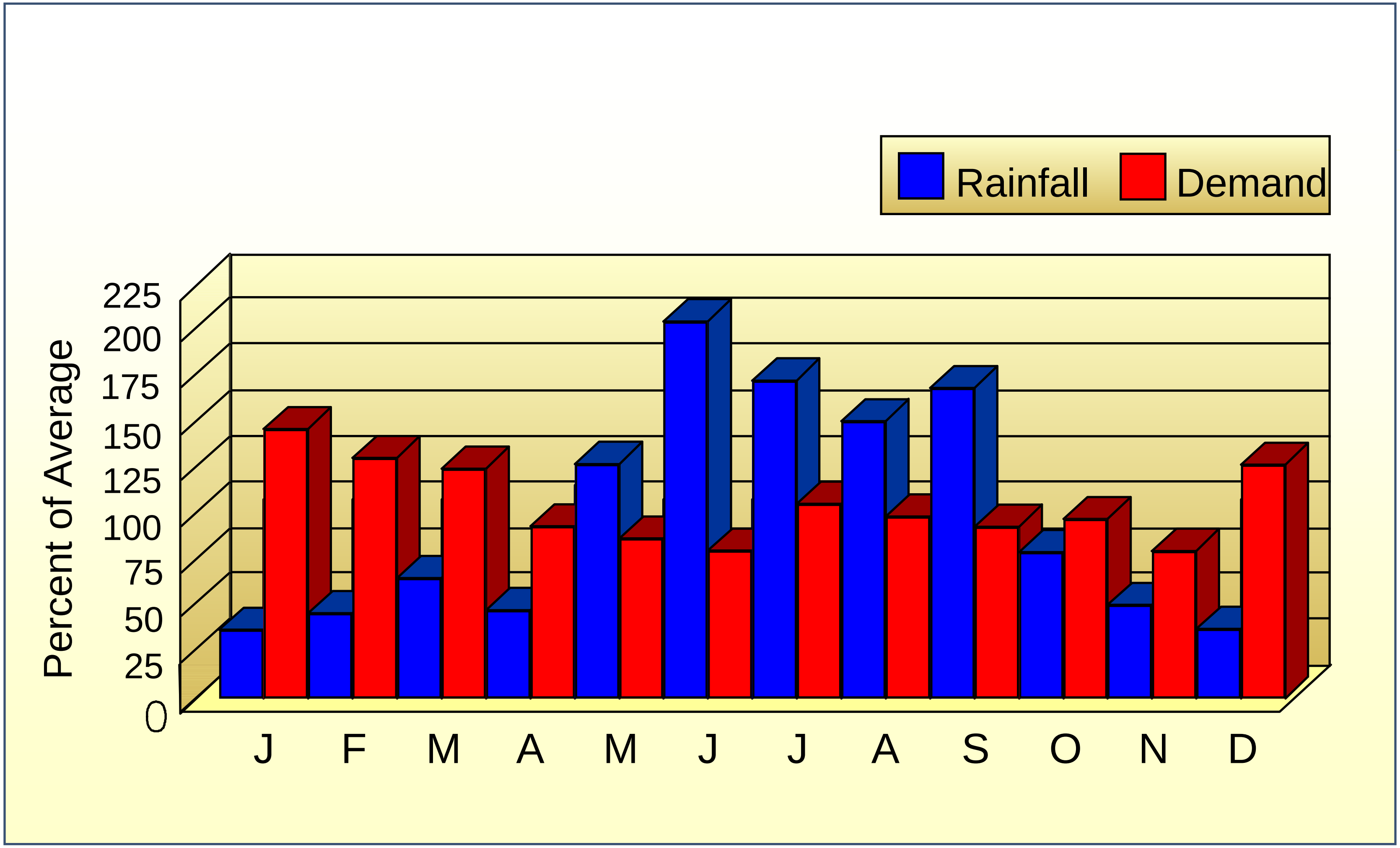
Create an underground reservoir



Recover to meet future use



Variability of climatic cycle creates additional demands on Natural System



Defining success of ASR systems?

There is no magic formula or equation!

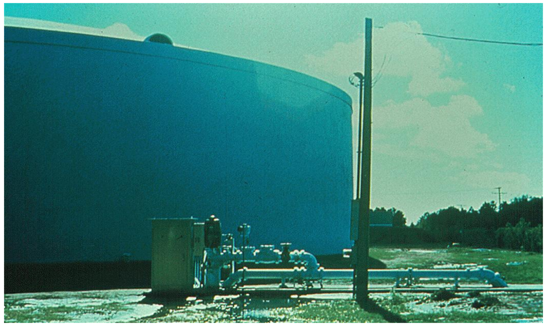
How to determine success?

How is recovery efficiency calculated?

How to compare with other options?

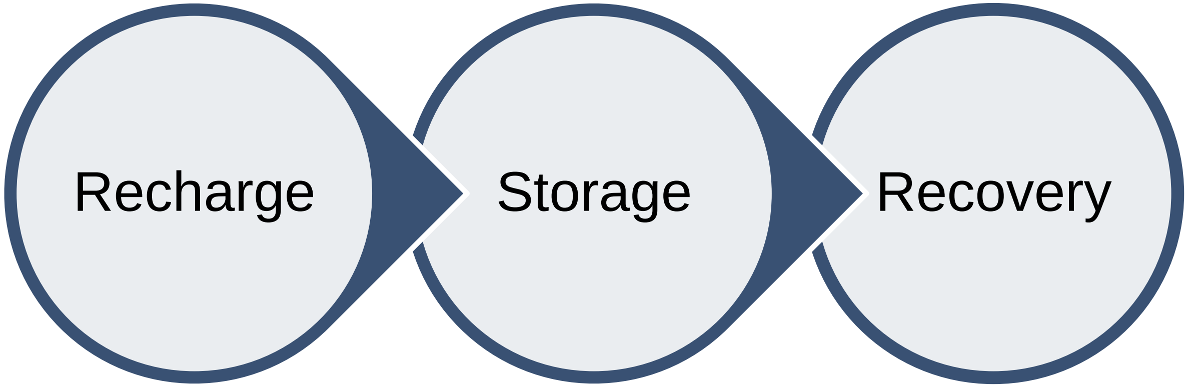
It's complicated…

- Source water quality
- Native water quality
- Intended use



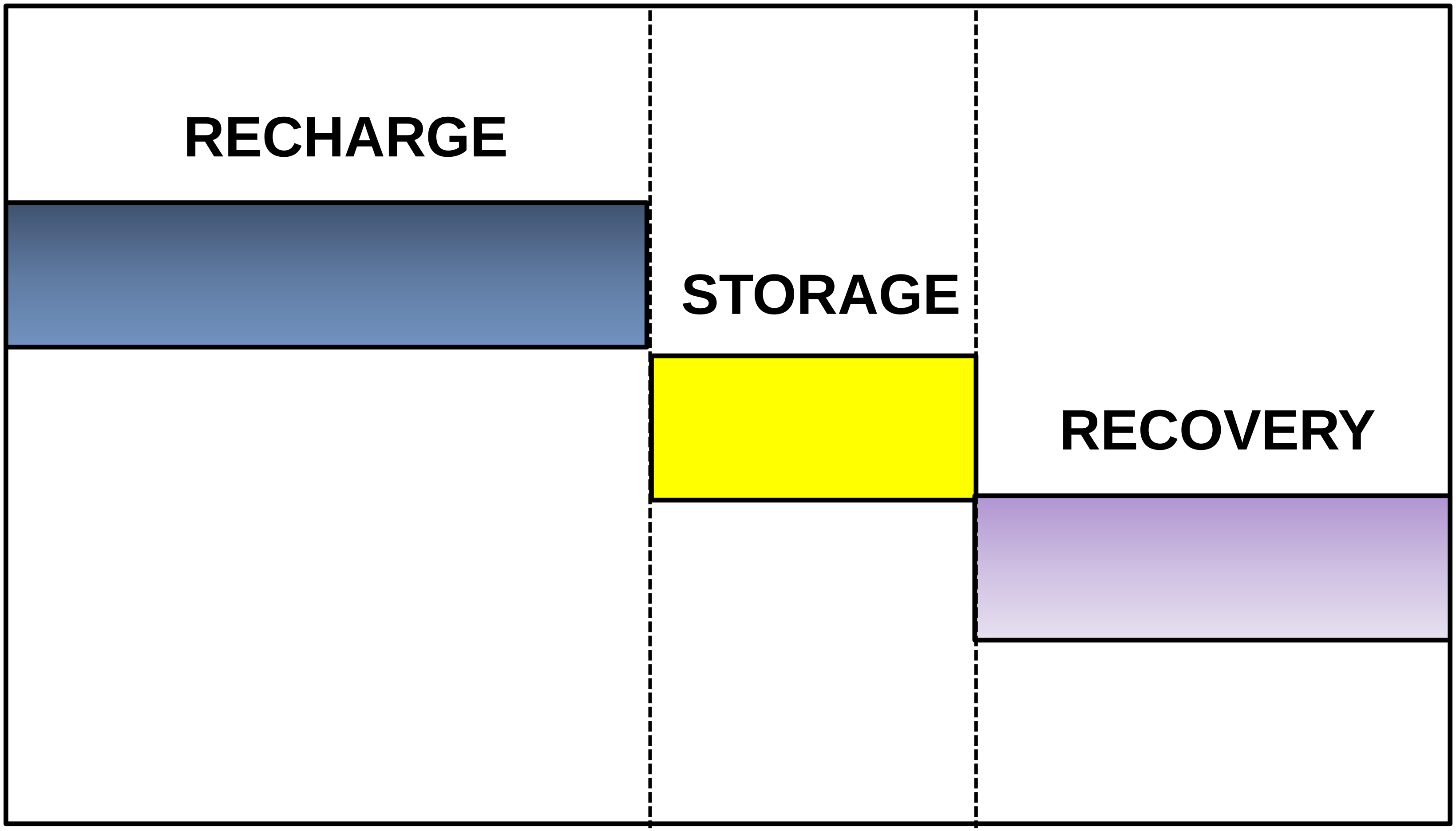
How do we know the concept works?

Typical phases of an ASR cycle

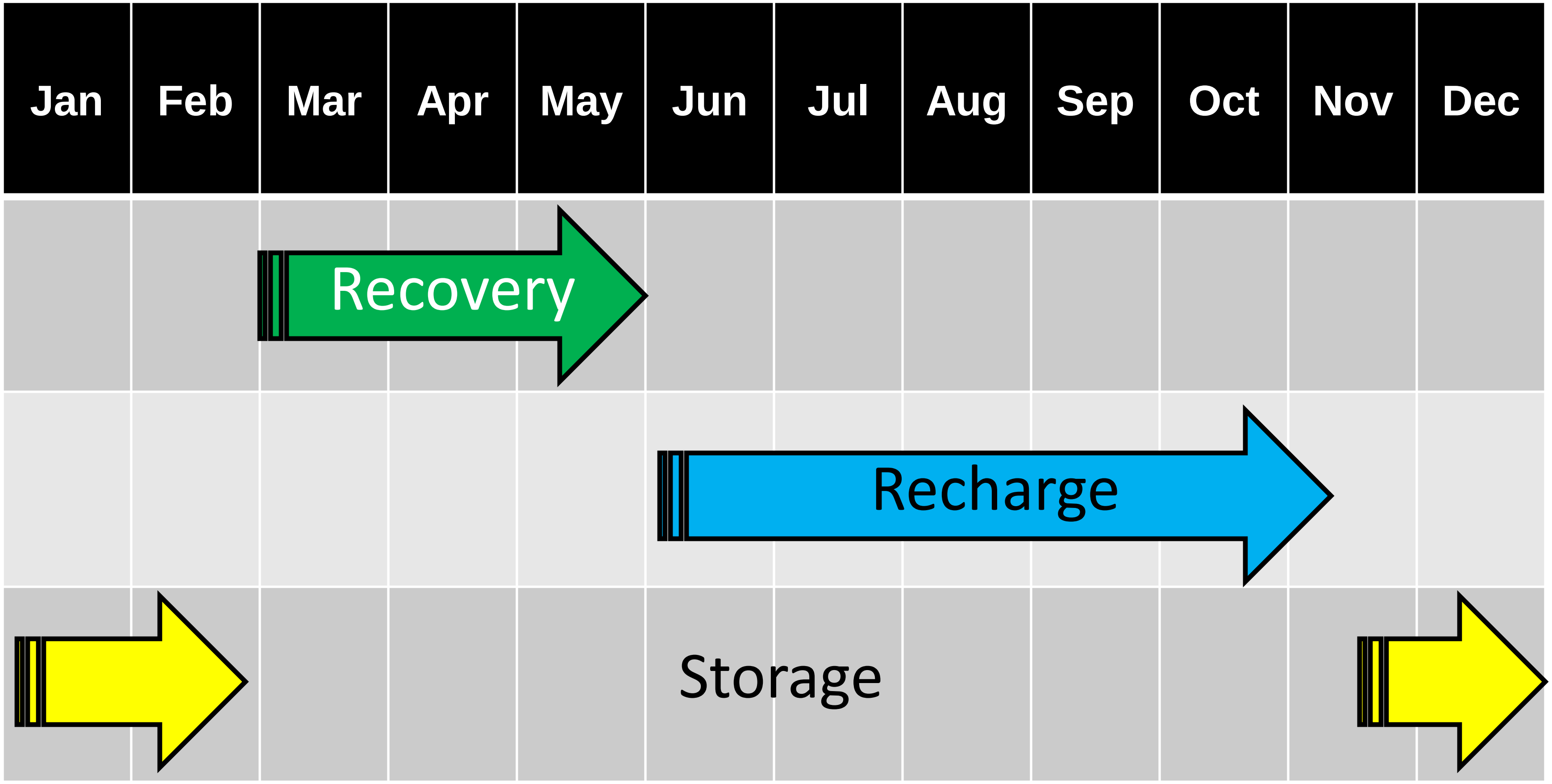


Cycle testing used to develop storage horizon and demonstrate system performance (i.e., validate design assumptions). Use typically results in improved performance.

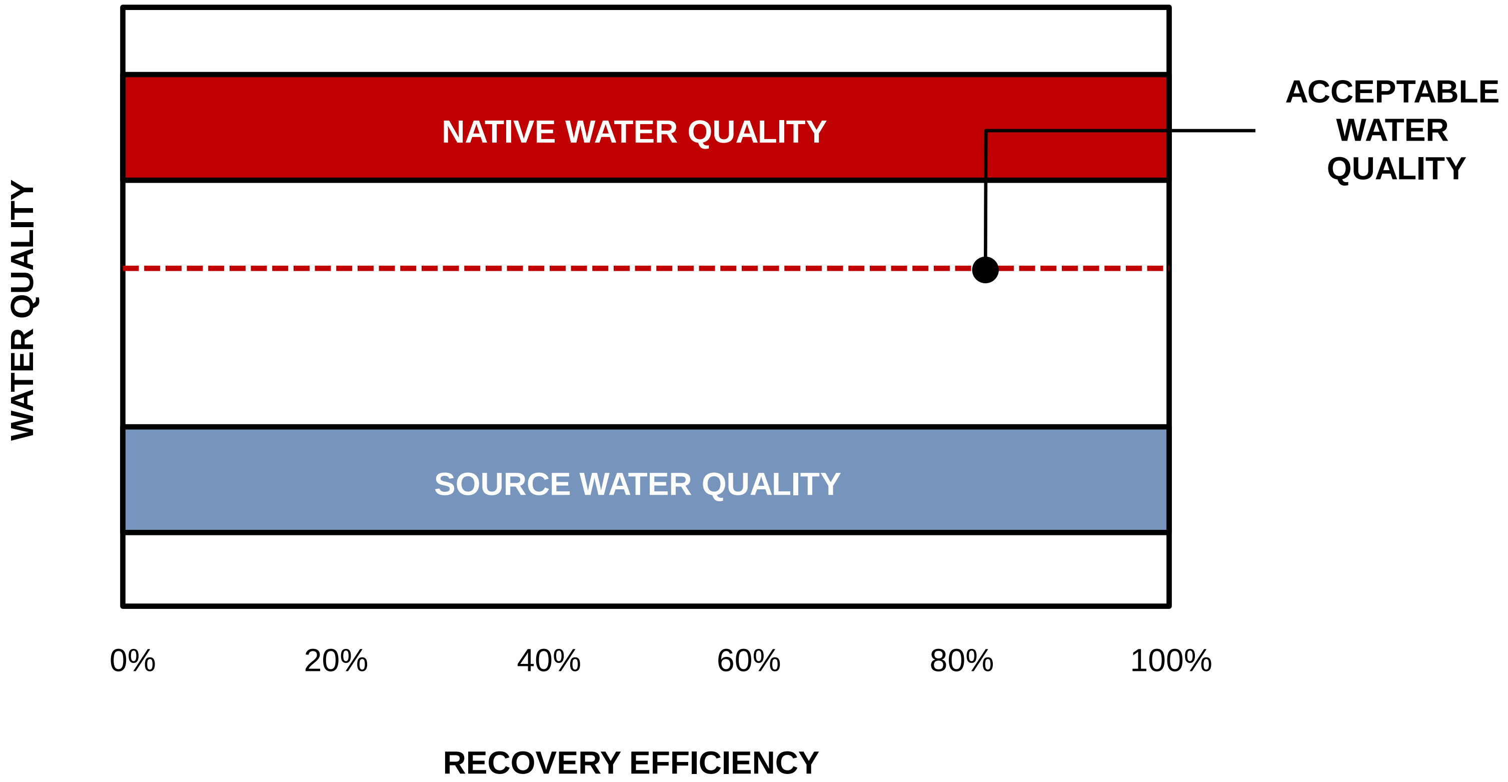
Typical ASR cycle…sequence of three activities



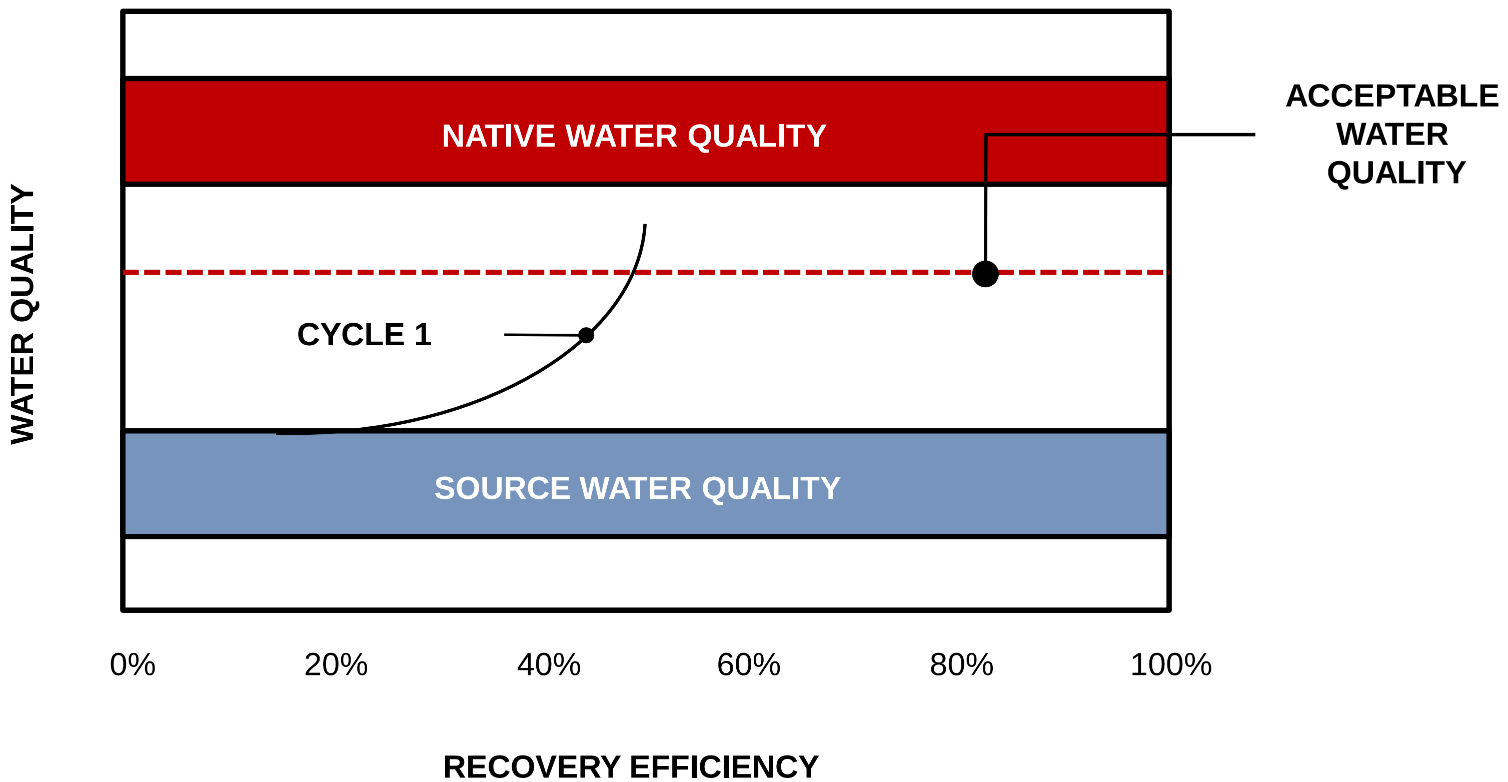
Water availability dictates storage zone development



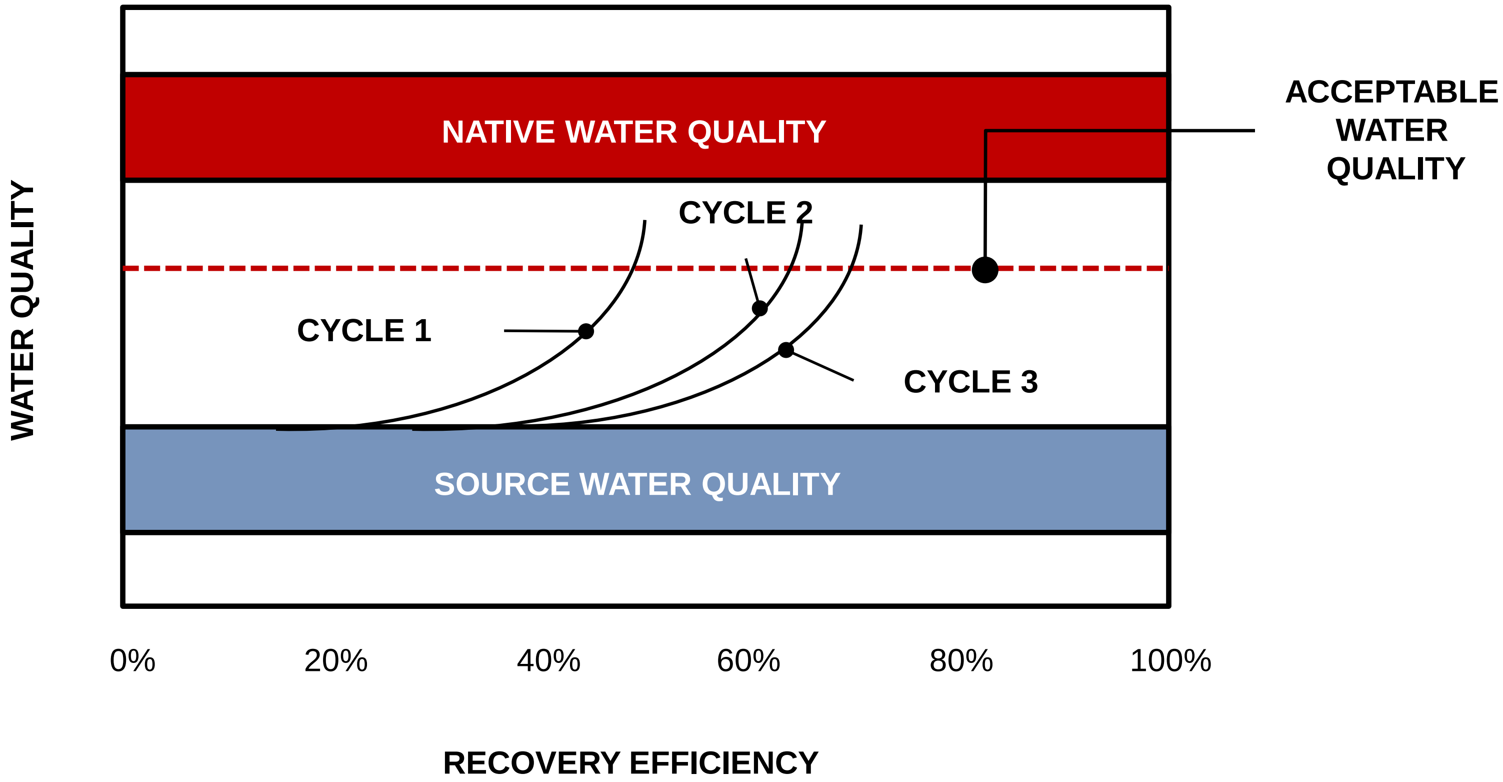
Recovered water quality is typically used to assess performance



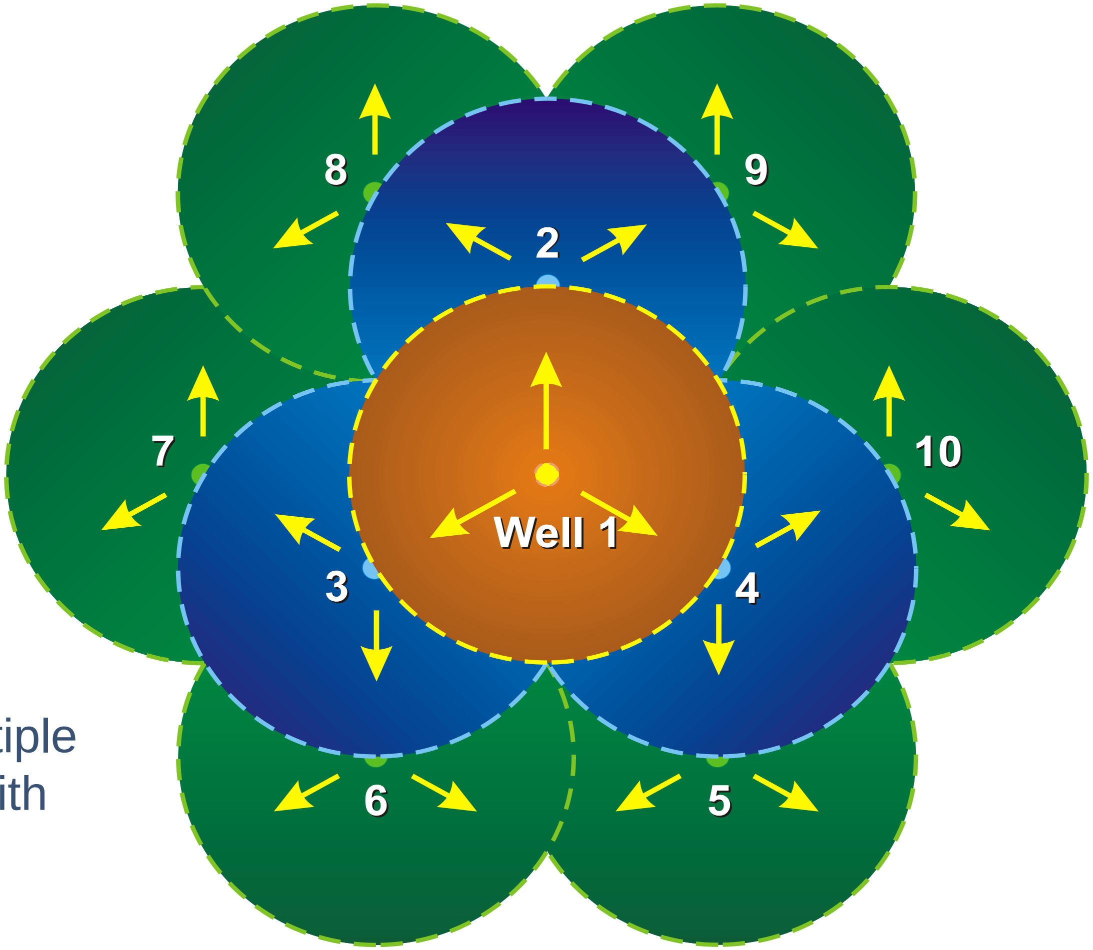
Acceptable targets are set with recovery until blend reaches a pre-set concentration



Recovered water quality should improve with successive cycles (i.e., storage zone development)

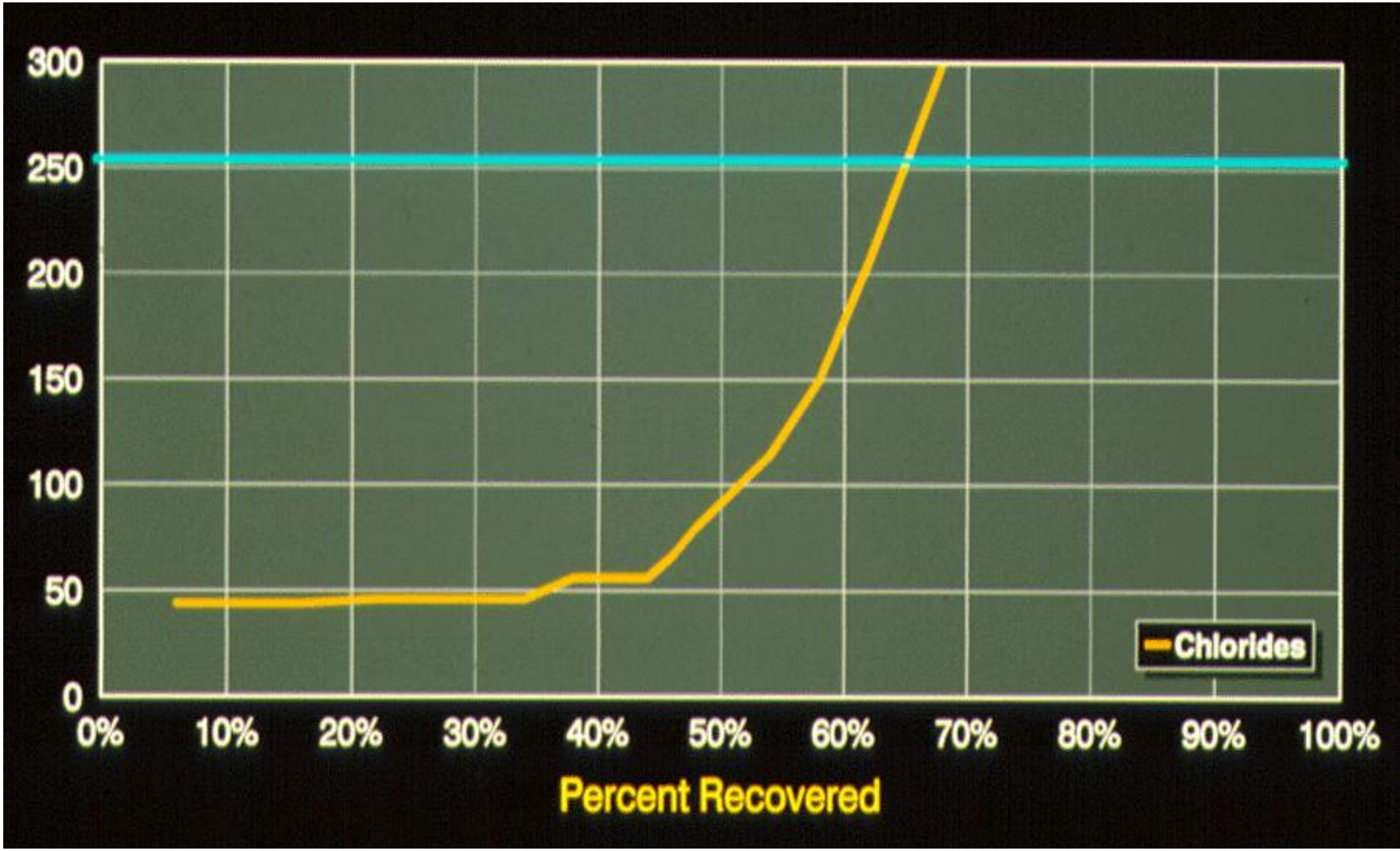


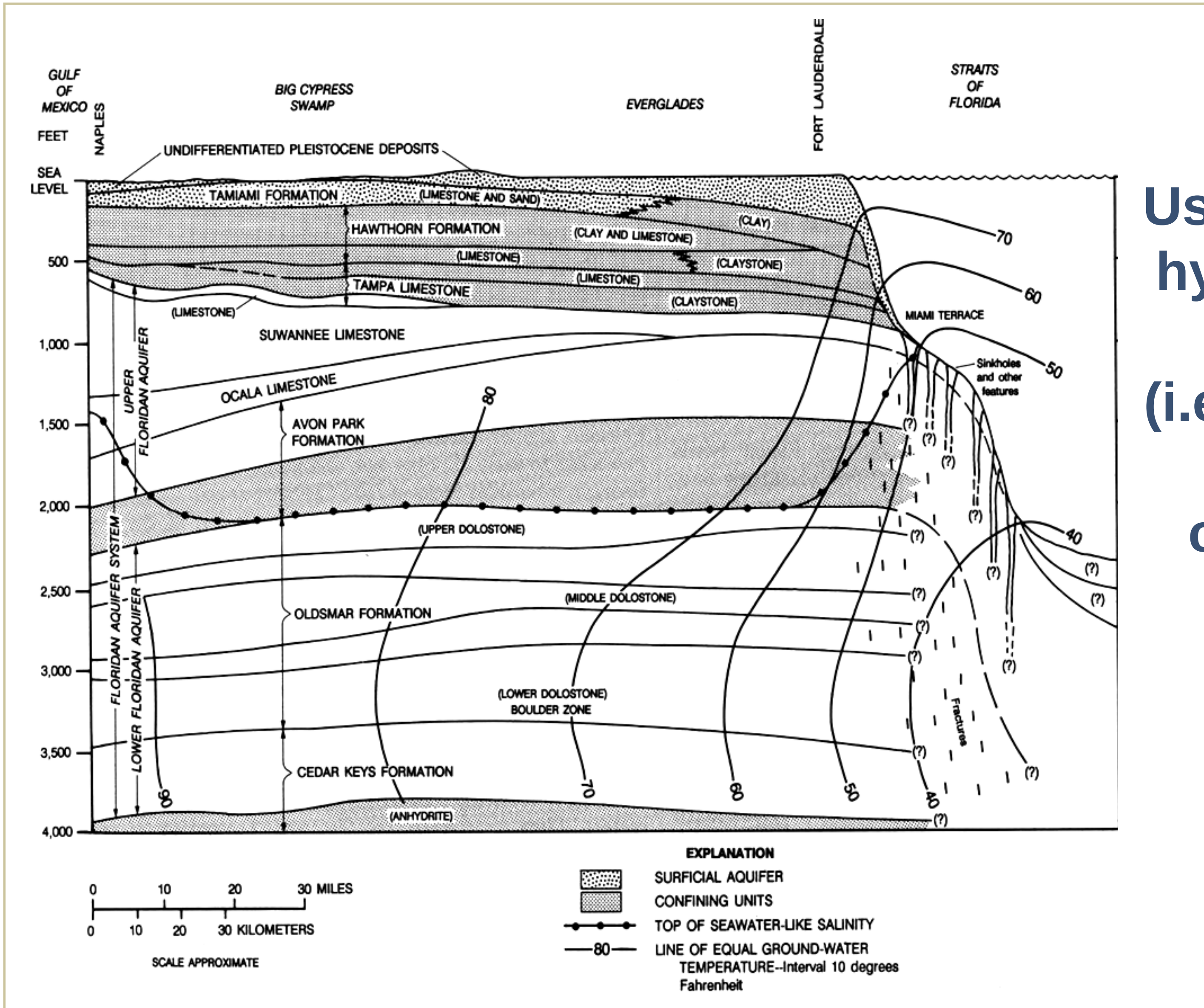
Modeling can be used to layout system and develop testing and monitoring plans



For example:
Layout of multiple well system with overlap

Typical ASR recovery curve

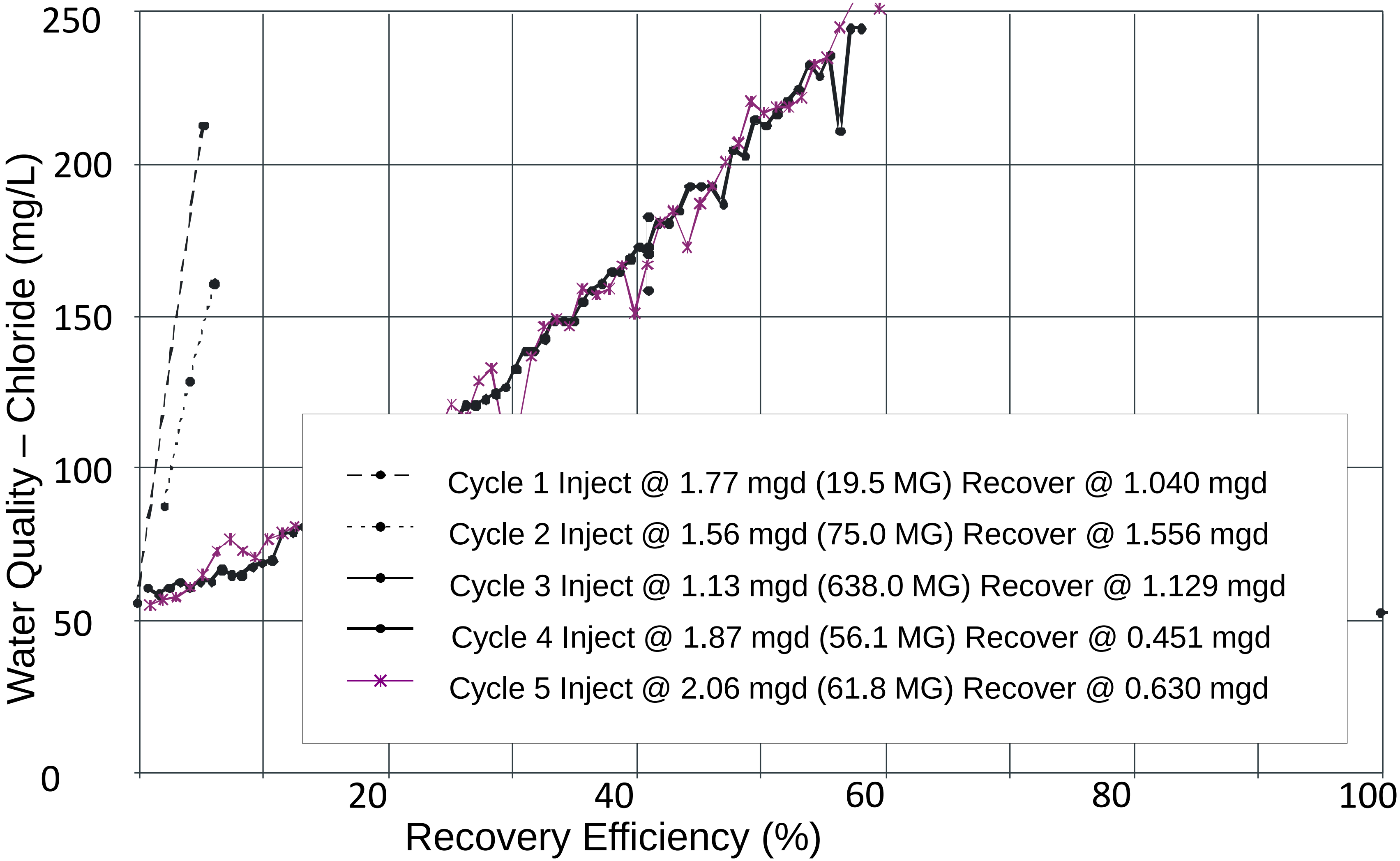




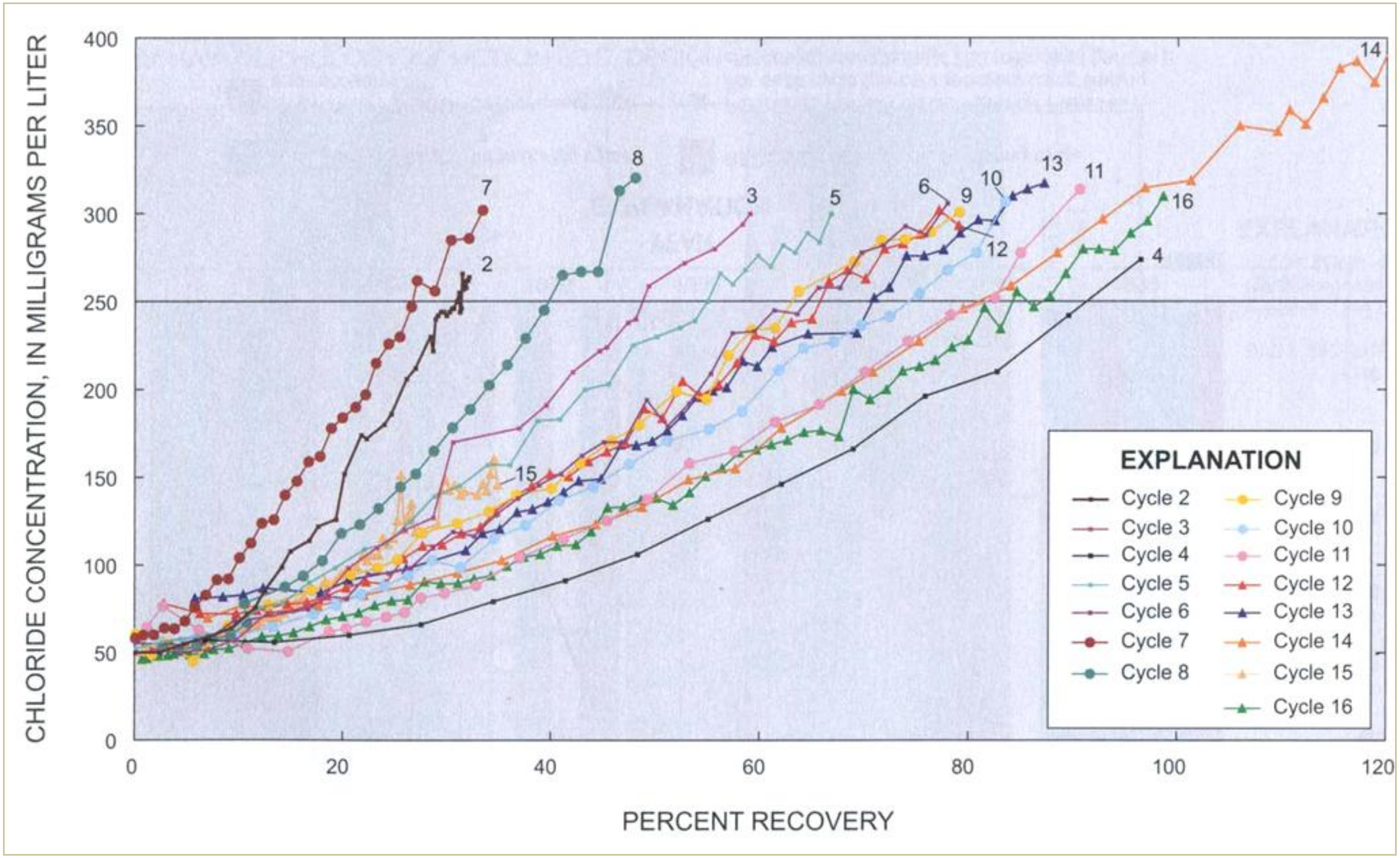
Use of existing hydrogeologic conditions (i.e., upper and lower confinement) is critical to maximizing recovery efficiencies

Figure 3 – Hydrogeologic Cross Section through South Florida (Meyer, 1989)

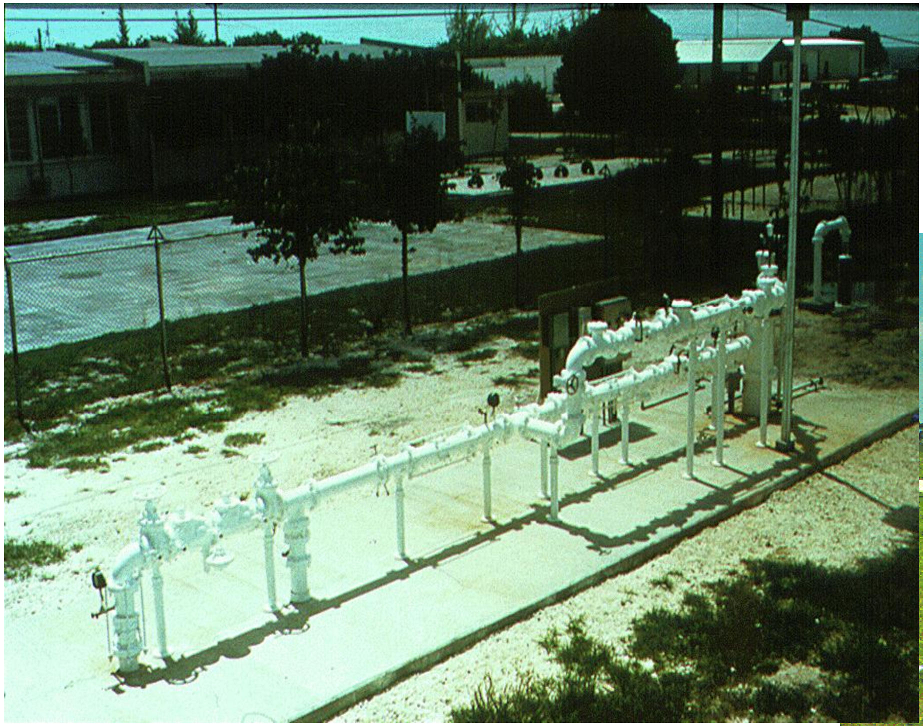
High recovery is possible if well is properly designed, tested and developed



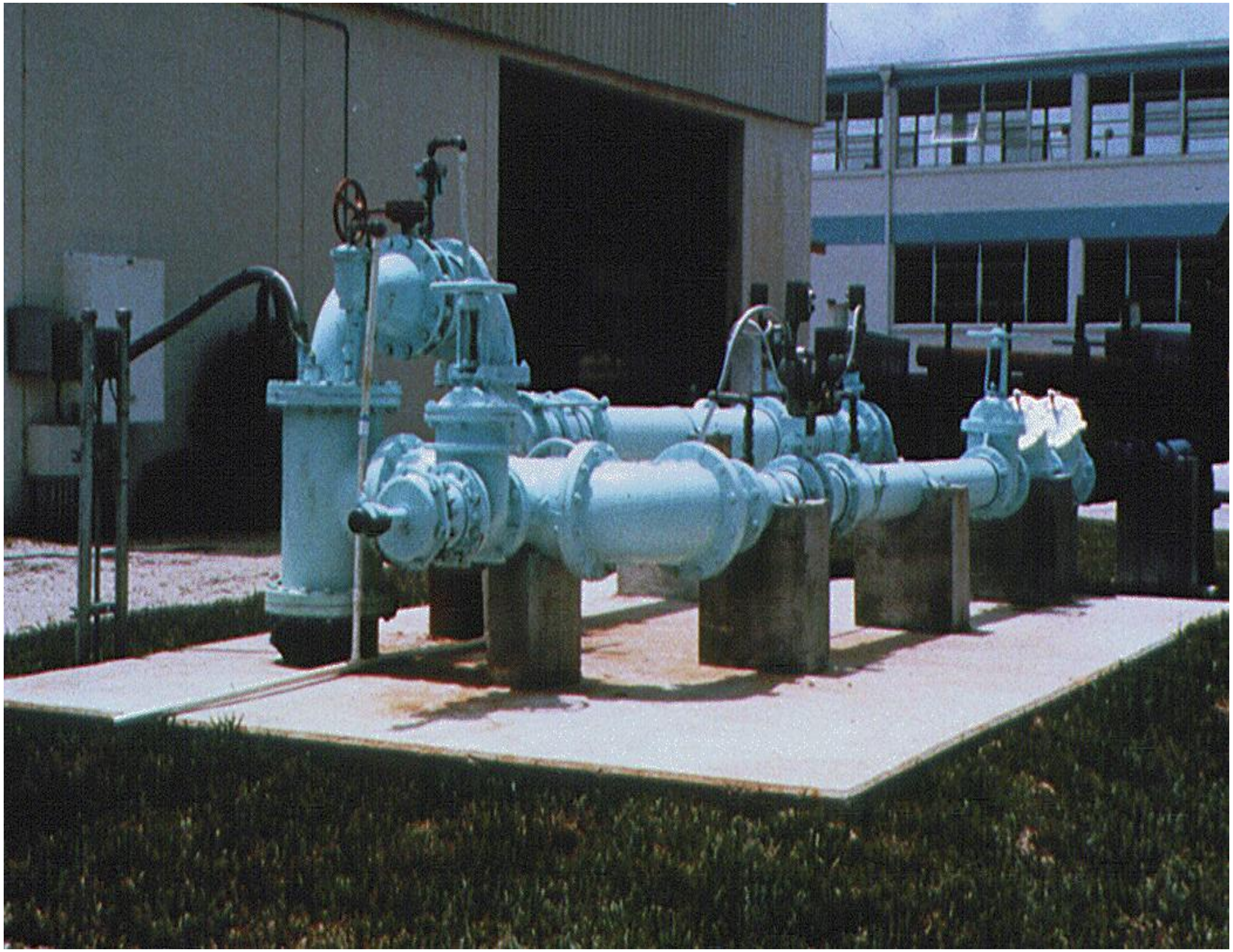
City of Boynton Beach is an example of storing treated water in a brackish setting



Typical wellheads

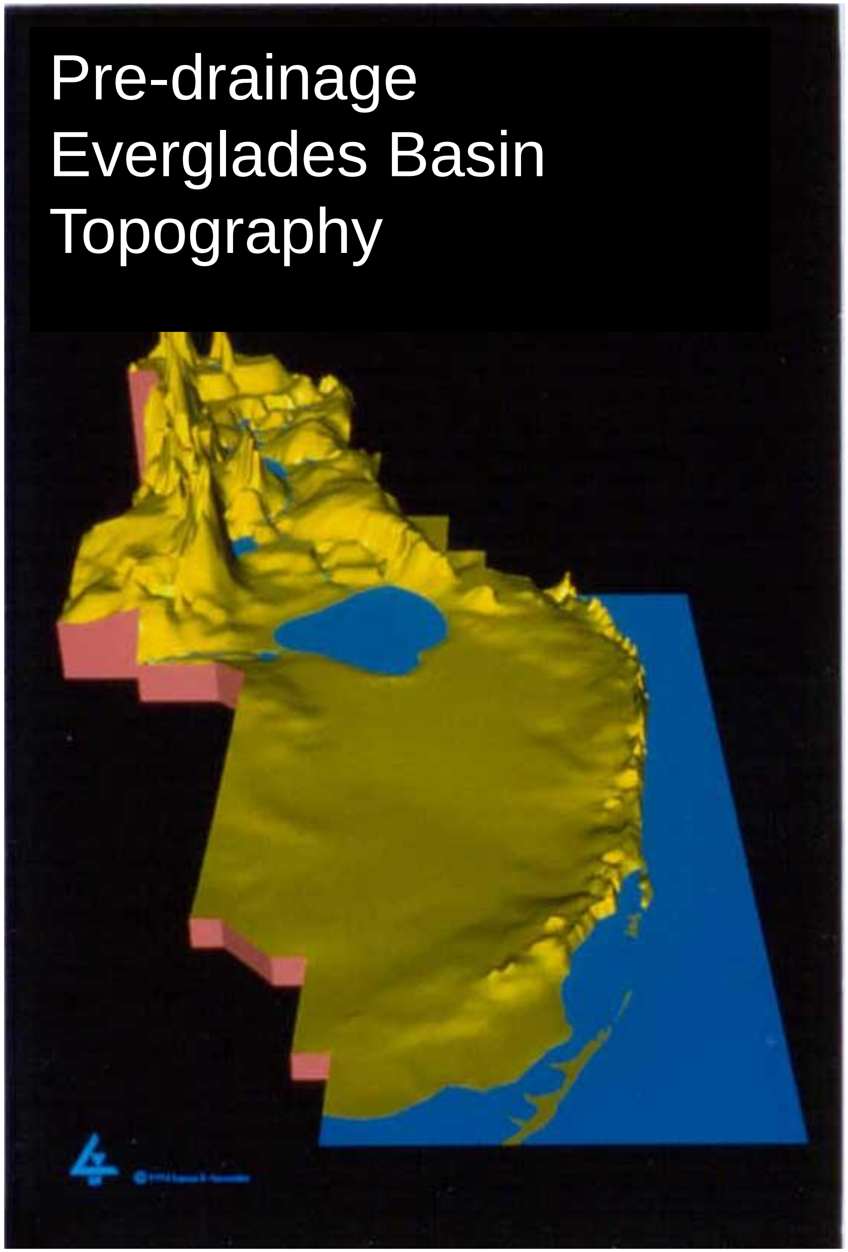


Potable water ASR facility – Boynton Beach



Surface reservoirs may be limited due to topography

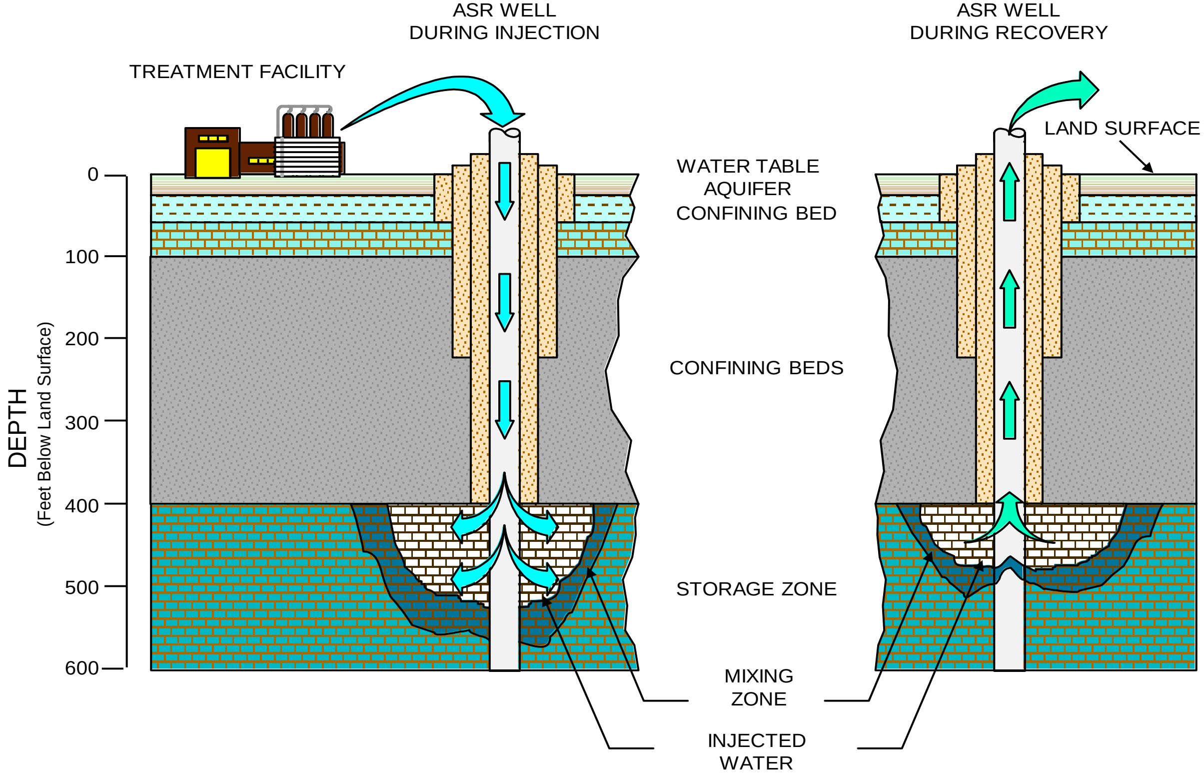
- High water table means shallow lakes
- High evapotranspiration rates
- Infrastructure designed for flood control, not water management
- High degree of runoff or high transmissivity of surficial aquifer



Regulations governing ASR

ASR is an excellent water management tool that has many functions

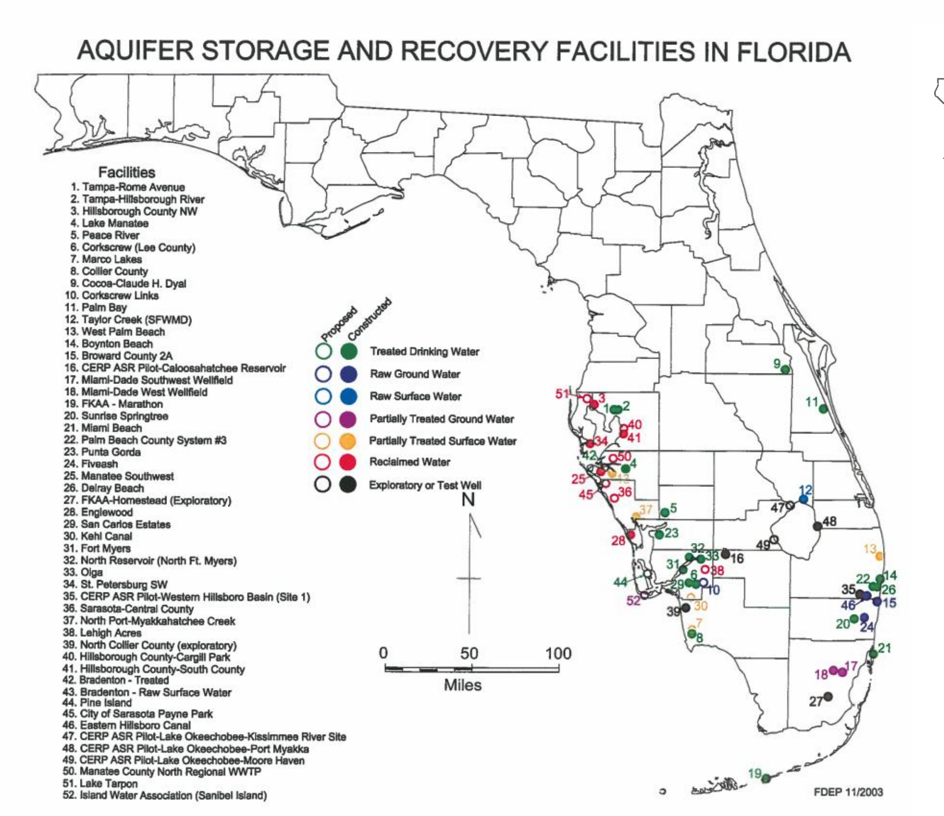
The ASR concept is simple and cost effective



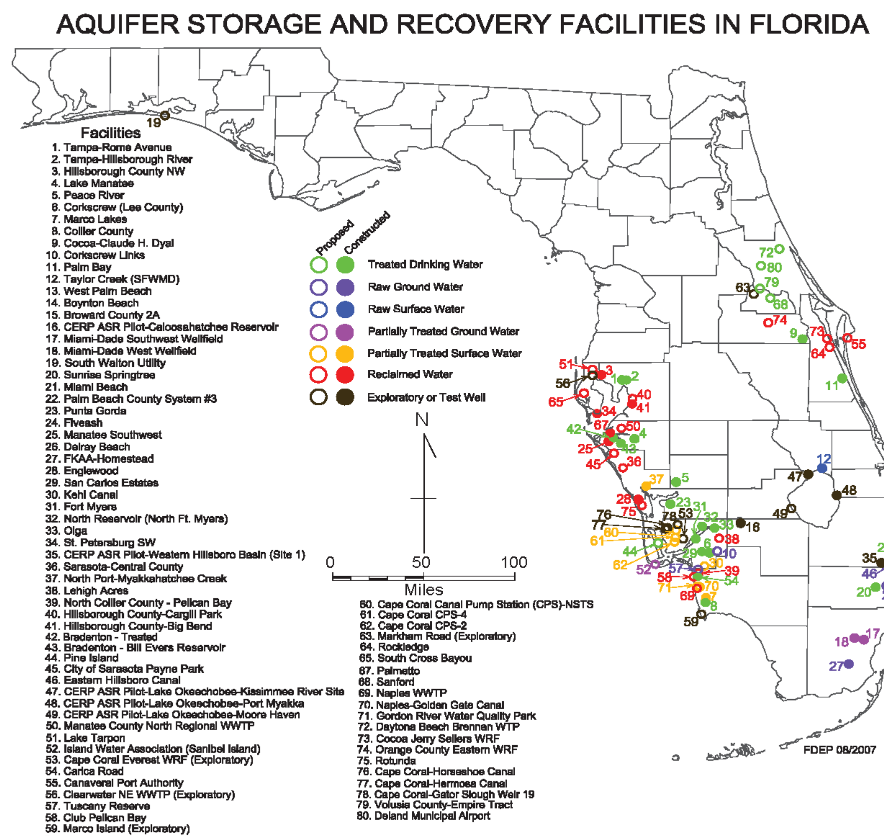
Aquifer Storage and Recovery entails storage of fluids in a suitable underground formation and recovery of that fluid for a future beneficial use.

Popularity of ASR continues to grow in Florida and across the country and beyond

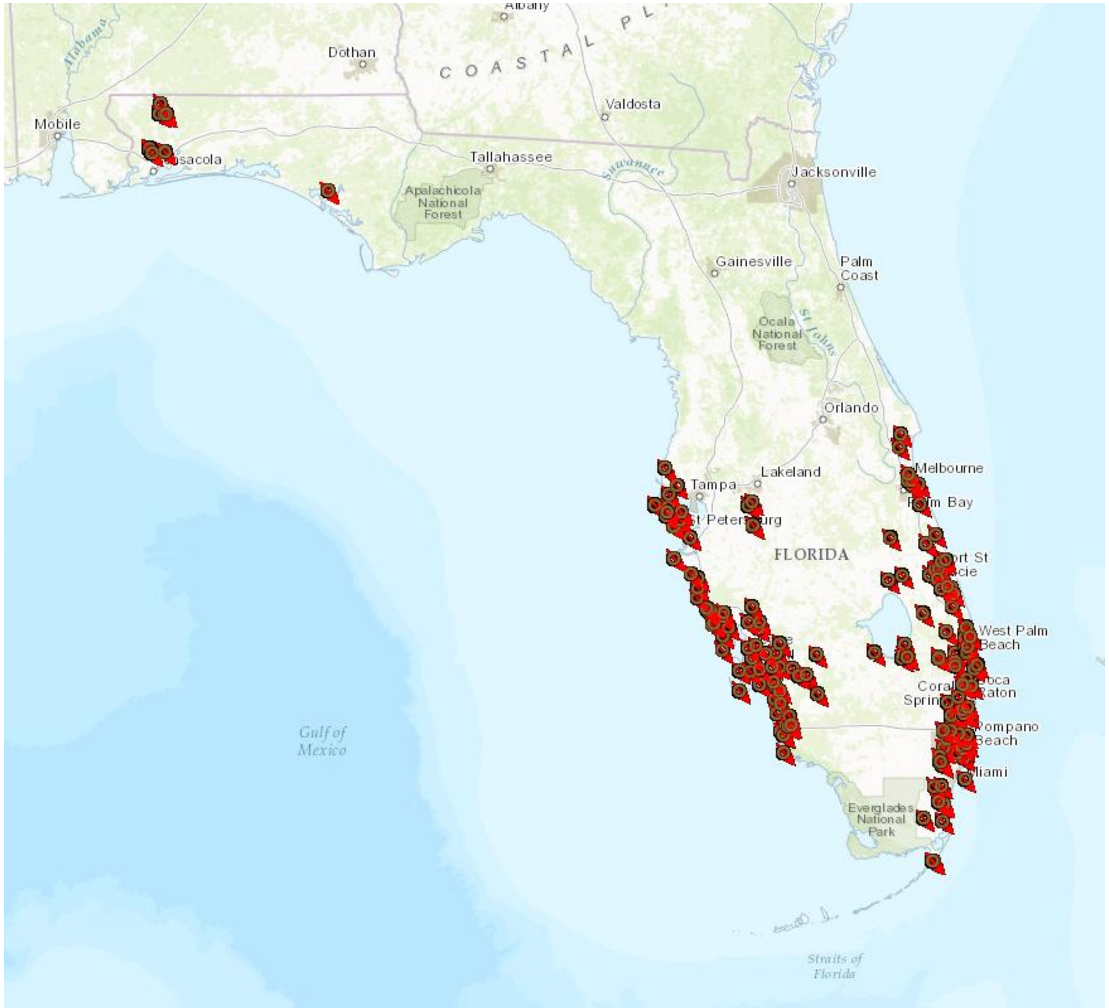
Florida in 2003

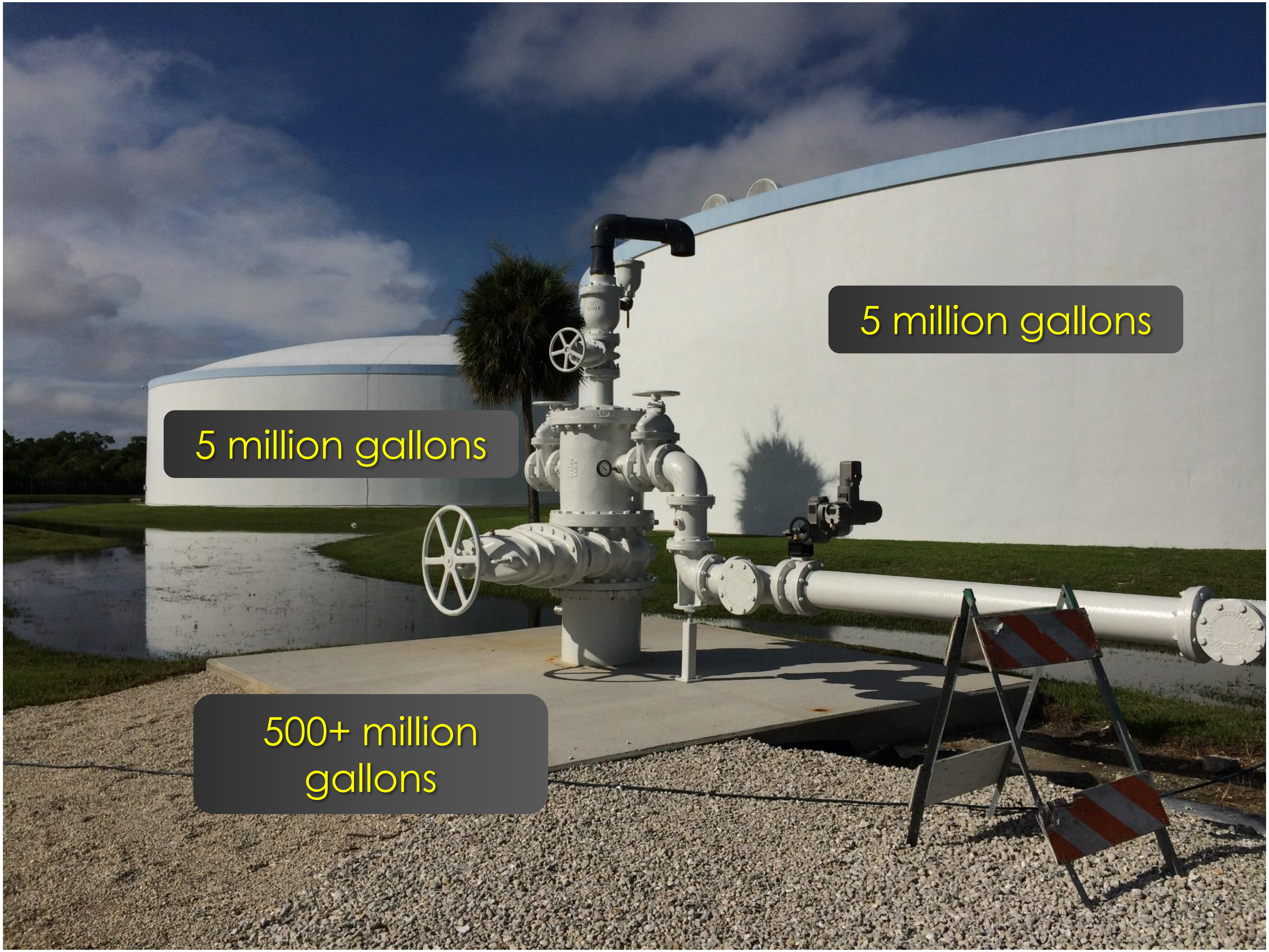


Florida in 2007



Florida ASR sites in 2016 per FDEP Oculus




5 million gallons
5 million gallons
500+ million gallons

The boss, and there are many

Who is ultimately responsible for enforcement?

- EPA and FDEP
- Water Management Districts
- Counties
- Local agencies

In some States, like Florida, the USEPA has transferred partial primacy to the State

FDEP has primacy for Class I, III, IV and V Wells

EPA manages Class II and VI Wells

FDEP has primacy for permitting of ASR systems in Florida which are Class V wells

ASR wells are permitted as an injection well

In Florida…

- ✓ Classification of injection wells in Florida fall under the Underground Injection Control or UIC program
- ✓ Chapter 62-528 is the primary section of the Florida Administrative Code (FAC) that governs the practice of underground injection in Florida
- ✓ Purpose of well (i.e., use) and water quality of receiving / storage zone are key for permitting of ASR wells

Aquifer classifications are based on water quality

Class F-I – Potable water use in single source unconfined aquifer with TDS less than 3,000 mg/L

Class G-I – Potable water use in single source confined aquifer with TDS less than 3,000 mg/L

Class G-II – Potable water use in aquifers with TDS less than 10,000 mg/L

Class G-III – Non-potable water use, groundwater in unconfined aquifer with TDS greater than 10,000 mg/L

Class G-IV – Non-potable use, groundwater in confined aquifer with a TDS of 10,000 mg/L or greater

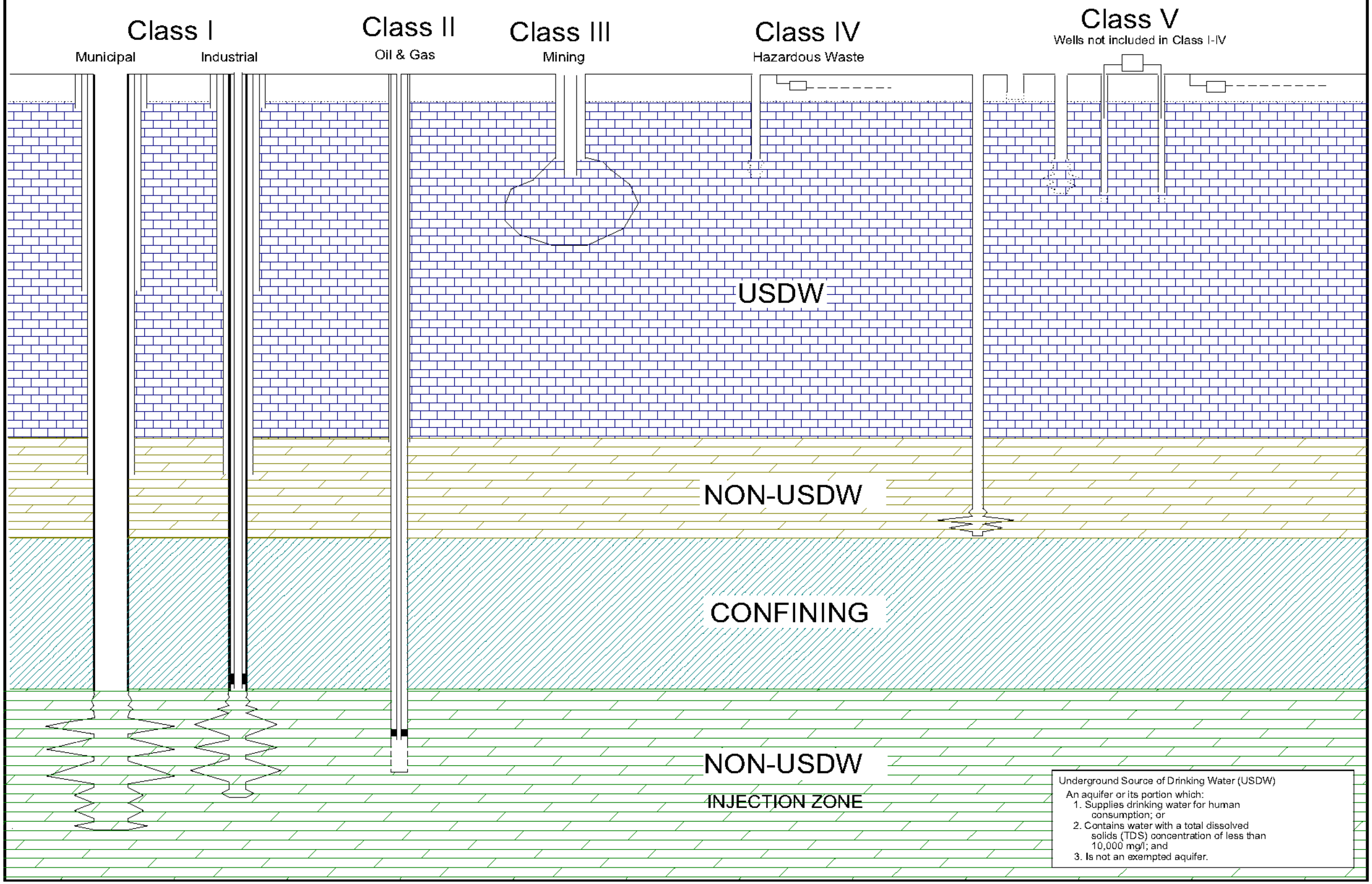
Are these classifications applicable today?

Classification of Injection Wells

Based on FAC 62-528.300

- Class I – Municipal and Industrial (tubing and packer) wells
- Class II – Oil and natural gas
- Class III – Mining
- Class IV – Hazardous waste *(Not Permitted in Florida)*
- Class V – Wells not included in Classes I-IV
- Class VI – Carbon dioxide

INJECTION WELL CLASSES



What are Class V Injection Wells?

Class V Injection wells are well that…

- Only injection wells not included in Class I, II, III, or IV are Class V wells, which are grouped together for the purpose of permitting.
- They are categorized in 9 groups as defined in FAC 62-528.300

Class V wells are categorized in Groups

Listing of groups from FAC 62-528

Group 1 – Thermal exchange process wells

Group 2 – Aquifer recharge wells

Group 3 – Domestic wastewater wells

Group 4 – Non-domestic wastewater wells

Group 5 – Mining or mineral extraction wells

Group 6 – Stormwater wells

Group 7 – Aquifer Storage and Recovery wells

Group 8 – Well regulated under additional Federal requirements

Group 9 – Other Class V wells

Class V – Group 2

Aquifer Recharge Wells

a. *Recharge wells used to replenish, augment, or store water in an aquifer;*

b. Salt water intrusion barrier wells used to inject water into a fresh water aquifer to prevent the intrusion of salt water into the fresh water;

c. Subsidence control wells (not used for the purpose of oil or natural gas production) used to inject fluids into a zone which does not produce oil or gas to reduce or eliminate subsidence associated with the overdraft of fresh water;

d. *Connector wells used to connect two aquifers to allow interchange of water between those aquifers*

Class V – Group 6

Stormwater Wells. Wells used to drain surface fluid, primarily storm run-off or for lake level control, into a subsurface formation.

Class V – Group 7

Aquifer Storage and Recovery System Wells. Wells associated with an aquifer storage and recovery facility where surface water or ground water is injected and stored for later recovery for potable or non-potable use. Wells used to store and recover effluent or reclaimed water from a domestic wastewater treatment plant shall be permitted as Group 3 wells.

What is the best option for permitting

Applications

ASR offers unique benefits depending on source water

Source water quality and quality of receiving zone are critical in design and performance of ASR systems

- ✓ Raw water
- ✓ Potable water
- ✓ Reclaimed water
- ✓ Stormwater
- ✓ Combination

Storage zone(s)

Storage zones affect permitting, monitoring and performance

Water quality

- Fresh water – TDS of less than 3,000 mg/L
- Brackish water – TDS between 3,000 and 10,000 mg/L
- Saline water – TDS greater than 10,000 mg/L
- Stacking across zones with varying native water quality

Underground Injection Control

Permitting Process

FDEP has a specific permitting process for injection wells. Class V injection wells are used for the storage or disposal of fluids into or above the USDW as described below:

- Major vs. Non-Major Class V Wells
- Aquifer storage and recovery (ASR)

The permitting process for

Class V Injection Wells

Major vs Non-Major

Hazen

Major vs Non-Major Class V Wells

Major Class V wells are permitted through the Tallahassee office. These wells include all ASR wells, aquifer recharge, exploratory and reverse osmosis wells. They also include domestic waste wells completed in a USDW.

Non-Major Class V wells are permitted through the district offices. These wells include domestic wastewater wells below the USDW, closed loop heat pump/ air conditioning return flow wells, swimming pool drainage wells, stormwater wells, and remediation wells.

The permitting process for

Class V Injection Wells

Aquifer Storage and Recovery (ASR)

Aquifer Storage and Recovery Wells

Aquifer storage and recovery (ASR) is a mechanism for storing water underground through an injection well to be withdrawn in the future for beneficial purposes. Typically, water is stored during times of excess supply for use when supplies are limited. ASR wells are capable of storing treated drinking water as well as reclaimed water, surface water, or groundwater. **However, whether treated or not, water injected into ASR wells must meet Florida's drinking water quality standards.** The level of treatment required after storage depends on the use of the water, whether for public consumption, surface water augmentation, wetlands enhancement, irrigation, saltwater intrusion barrier, etc. Because ASR provides for the storage of water that would otherwise be lost to tide or evaporation, it represents a crucial water supply management strategy for Florida’s future.

Is ASR common in Florida…yes

Primary source used in research was the FDEP Oculus

Process used in assimilating data

Oculus

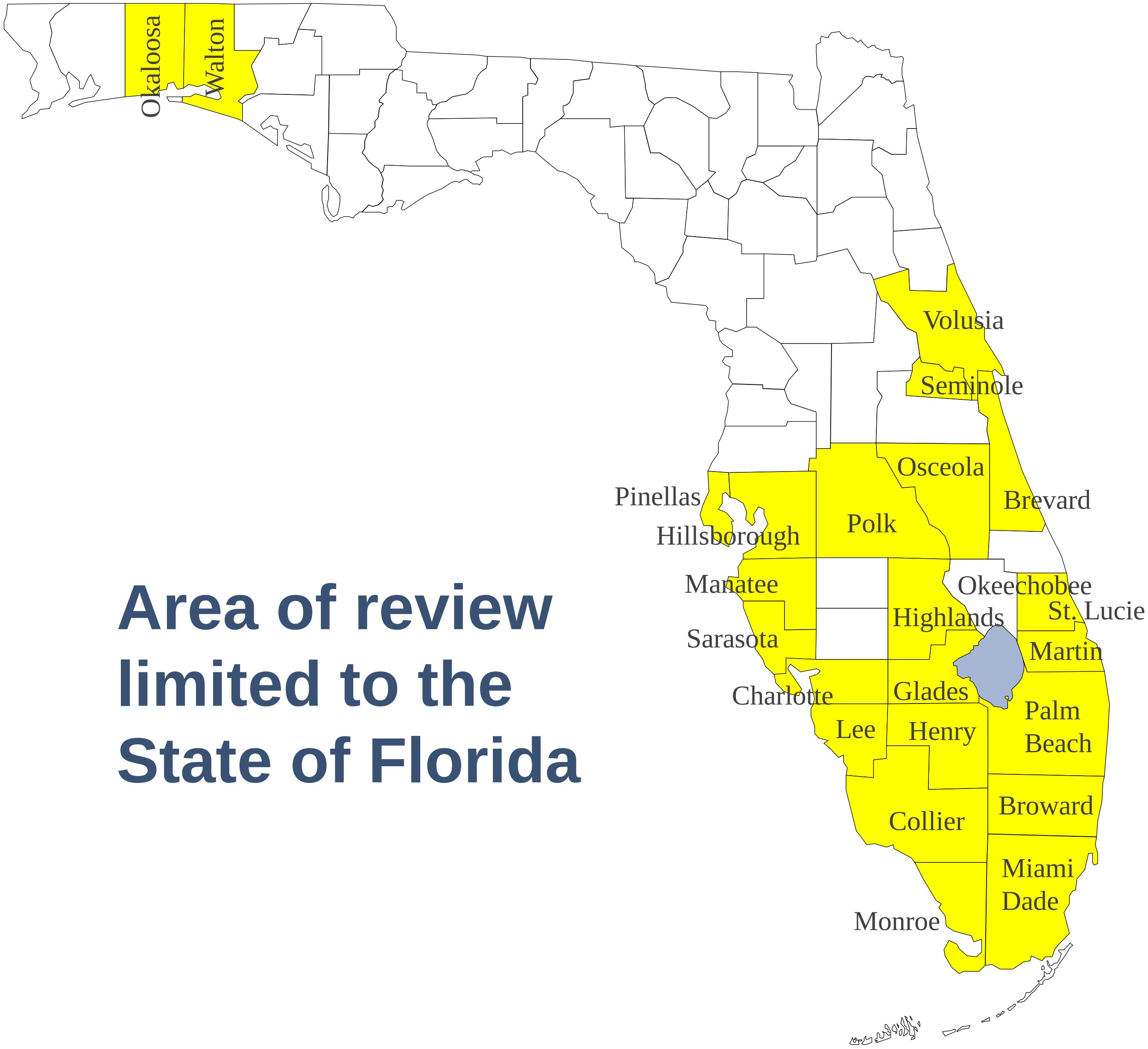
Starting point used to obtain attributes

Permits

Copy of permits used to confirm status and attributes

Old Files

Research well completion reports, publications to compare / validate the FDEP database



Florida has 67 Counties, 24 of which have ASR systems.

Area of review limited to the State of Florida

Facility status

1. Active
2. Active not permitted / registered
3. Closed, no groundwater monitoring
4. Inactive
5. Never operated, permit never used
6. Not associated with UIC
7. Permanently abandoned approved
8. Permanently abandoned not approved
9. Proposed
10. Transferred
11. Unable to field verify
12. Under construction
13. Closed, with groundwater monitoring

Attributes define the status of facilities and wells

Well status

1. Active
2. Active not permitted
3. Closed, no groundwater monitoring
4. Converted to monitor well
5. Inactive
6. Never operated, permit never used
7. Not associated with UIC status unknown
8. Permanently abandoned approved
9. Permanently abandoned not approved
10. Proposed
11. Transferred
12. Unable to field verify injection well
13. Under construction
14. Well was never constructed
15. Application pending
16. Closed with monitoring

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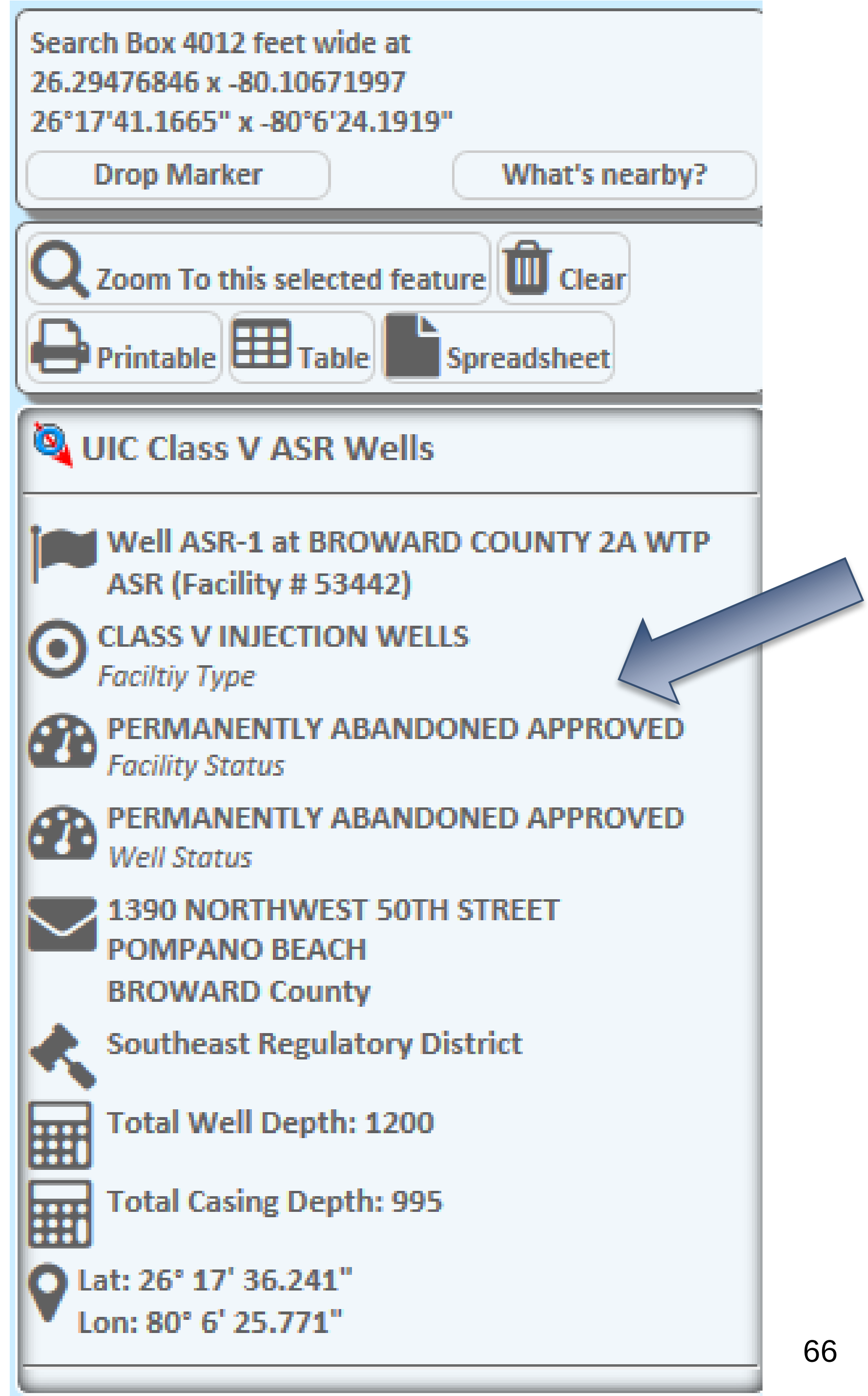

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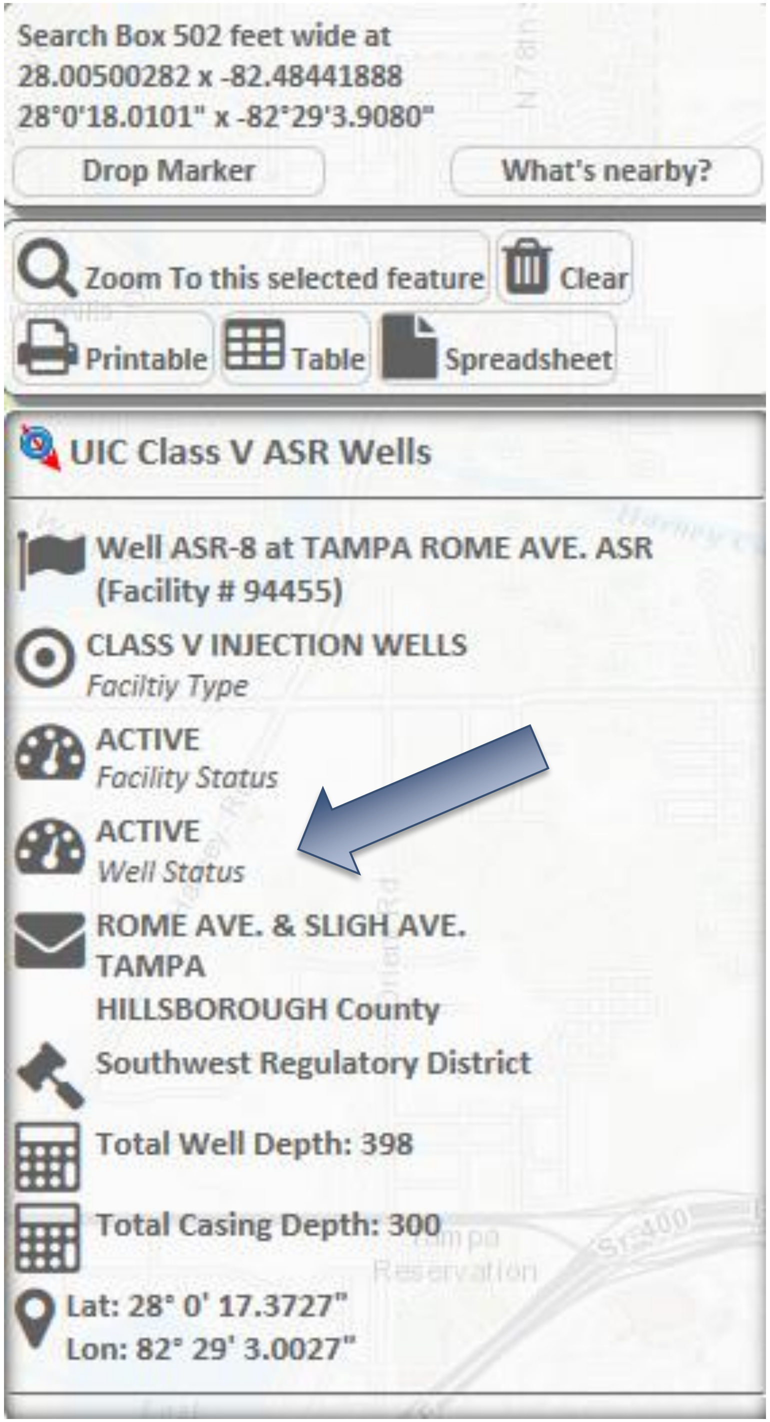

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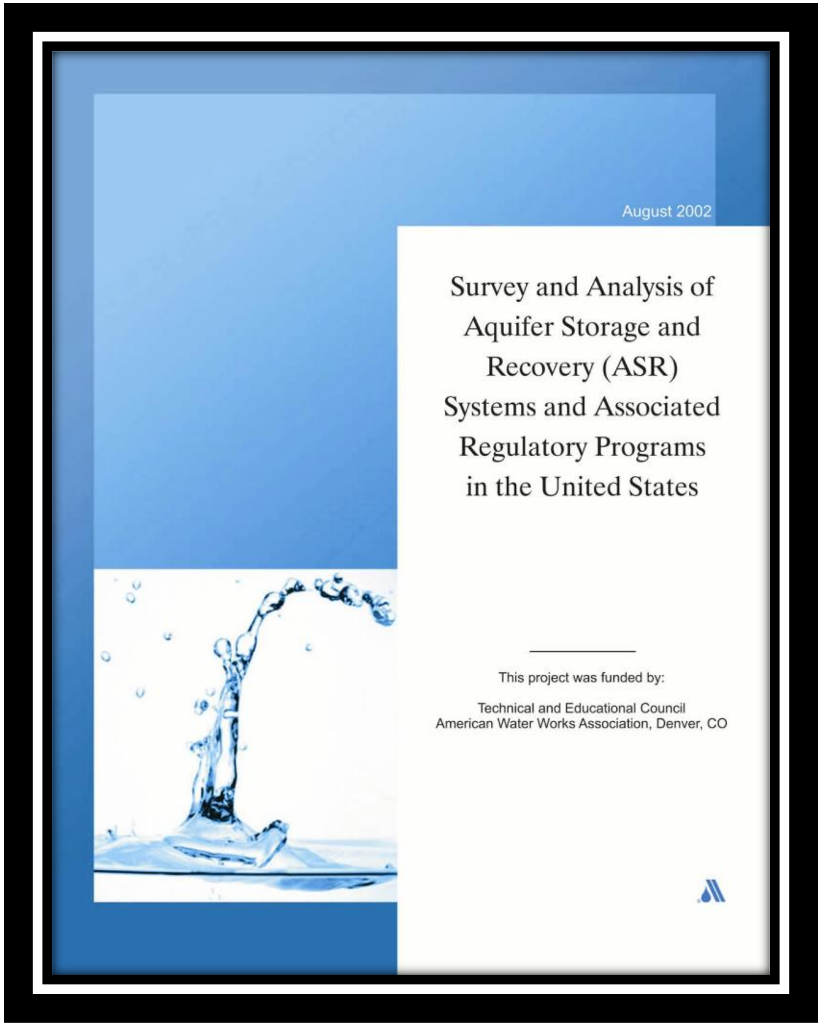
Previous reports and publications



Evaluating Current and Historical ASR Performance in Florida

April 2016

June E. Mirecki, PHD, PG et. al.

Most of the Counties with ASR Facilities appear to have water management challenges

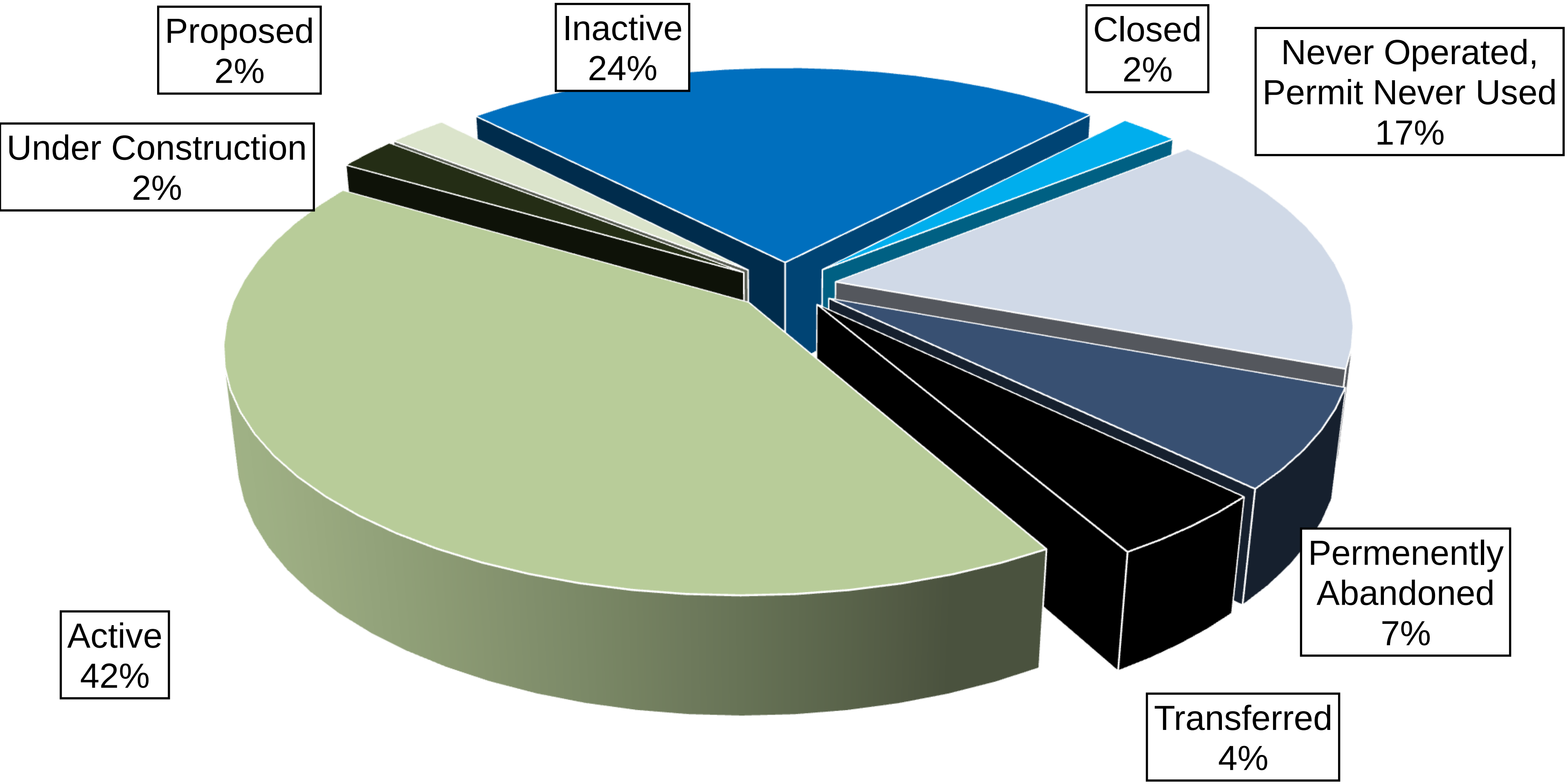
Of Florida's 67 Counties, 24 (35%) have ASR systems.

County with ASR

Accounting – Facility Status (91 facilities)

Facility Status	Number	Percentage
Active	39	42.9%
Active not permitted / registered	---	---
Closed, no groundwater monitoring	2	2.2%
Inactive	22	24.2%
Never operated, permit never used	15	16.5%
Not associated with UIC	---	---
Permanently abandoned approved	6	6.6%
Permanently abandoned, not approved	---	---
Proposed	1	1.1%
Transferred	4	4.4%
Unable to field verify	---	---
Under construction	2	2.2%
Closed with groundwater monitoring	---	---

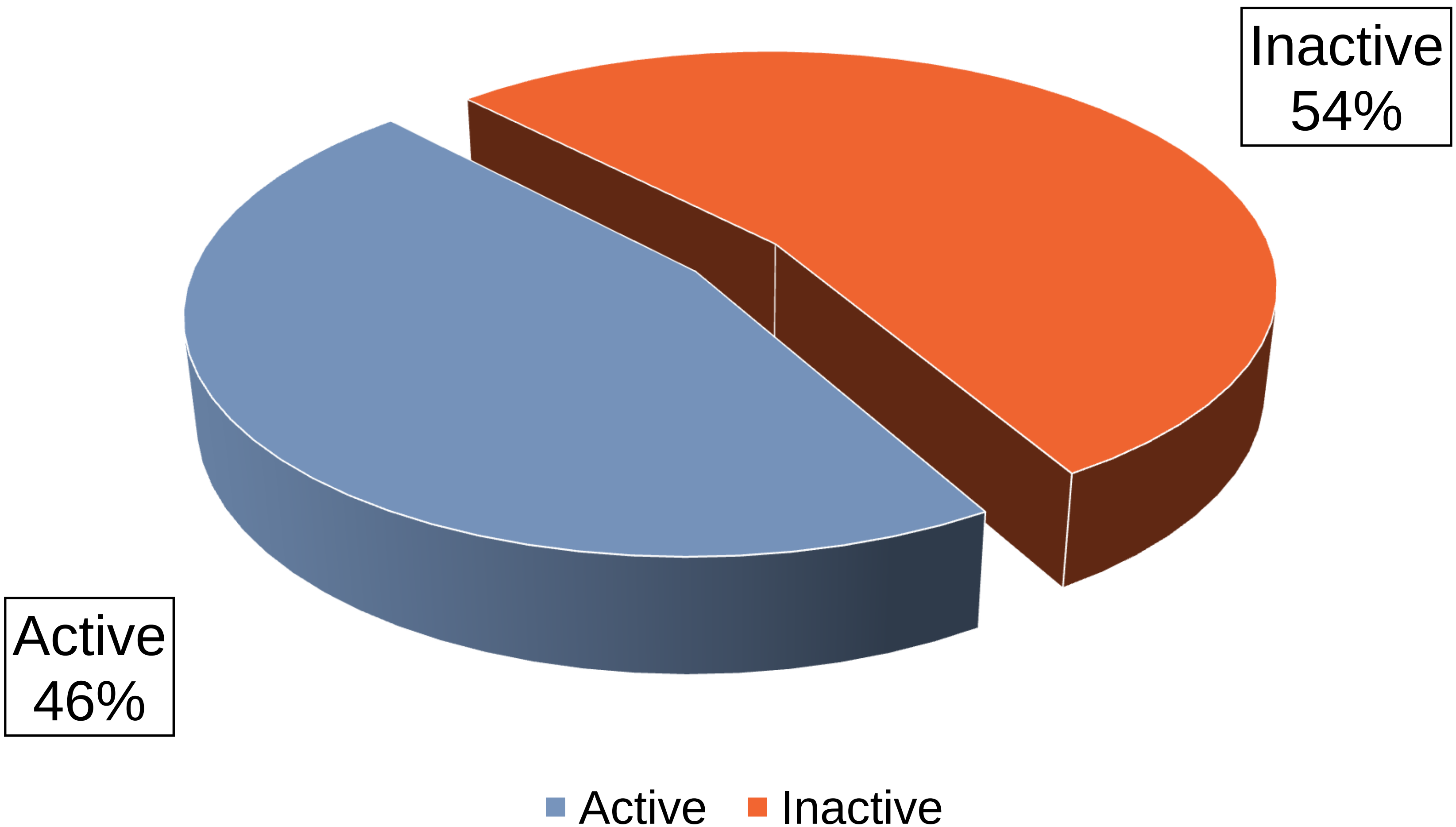
Status of ASR facilities



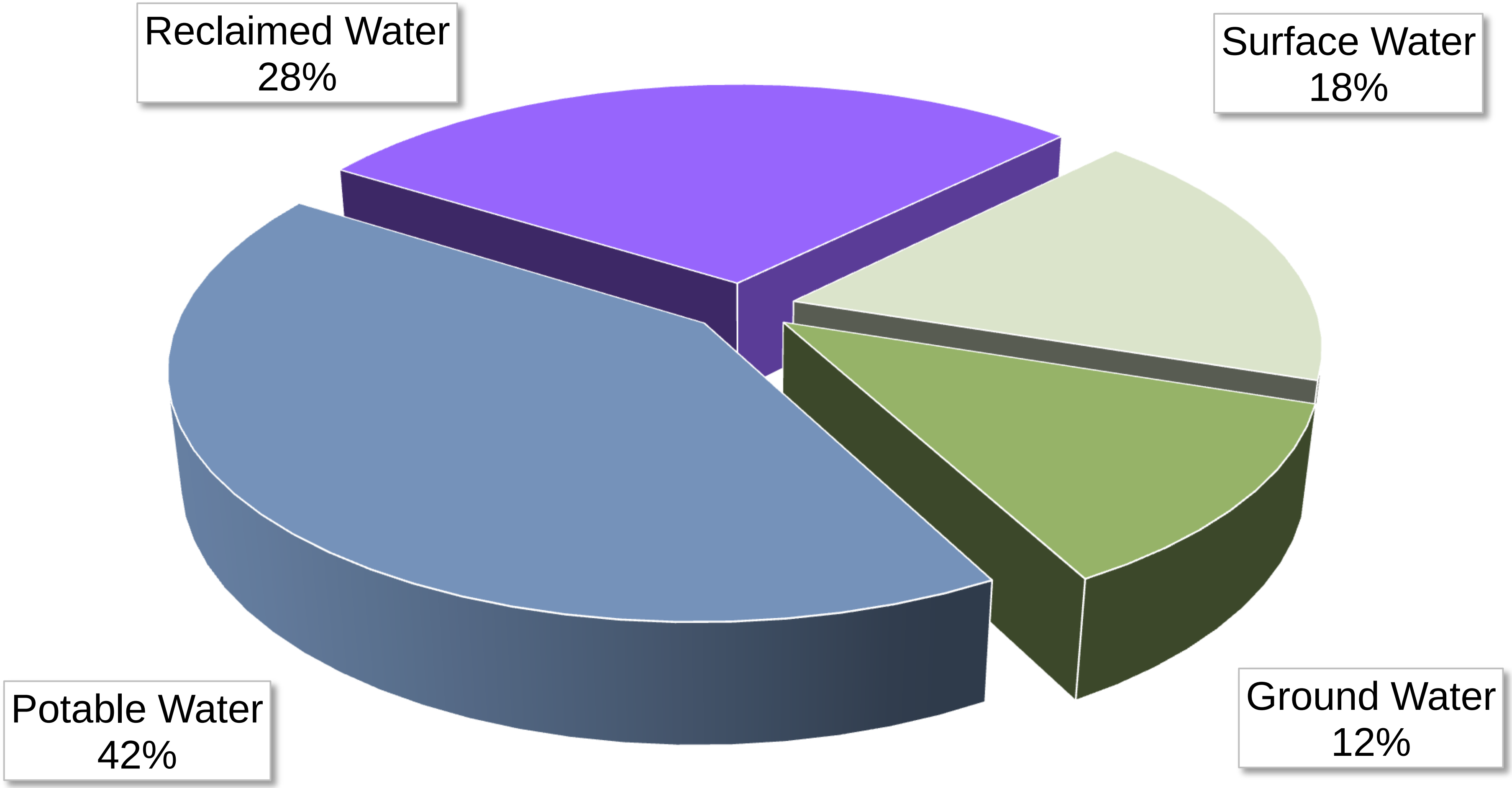
Accounting – Facility Status in terms of active and inactive

Facility Status	Number	Percentage	Number	Percentage
Active	39	42.9%	---	----
Closed, no groundwater monitoring	---	---	2	2.2%
Inactive	---	---	22	24.2%
Never operated, permit never used	---	---	15	16.5%
Permanently abandoned approved	---	---	6	6.6%
Proposed	1	1.1%	---	----
Transferred	---	---	4	4.4%
Under construction	2	2.2%	---	---
TOTALS	**42**	**46.2%**	**49**	**53.8%**

Facility status combined



Source water…intended purpose



Storage zone water quality *(ESTIMATED)*

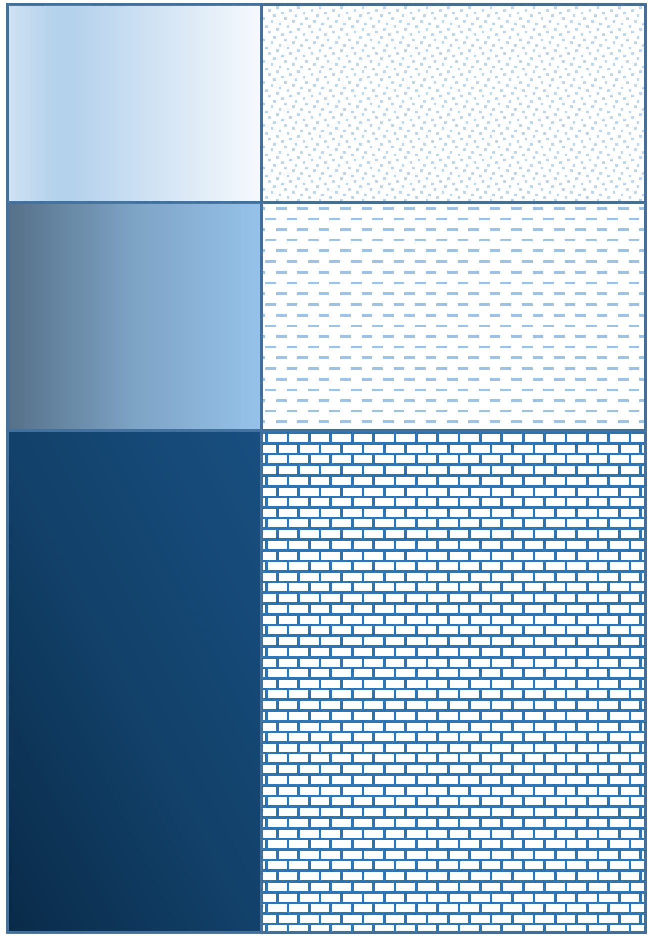
Fresh

TDS ~ 3,000 mg/L

Brackish

TDS ~ 10,000 mg/L

Saline



Approximately 64%

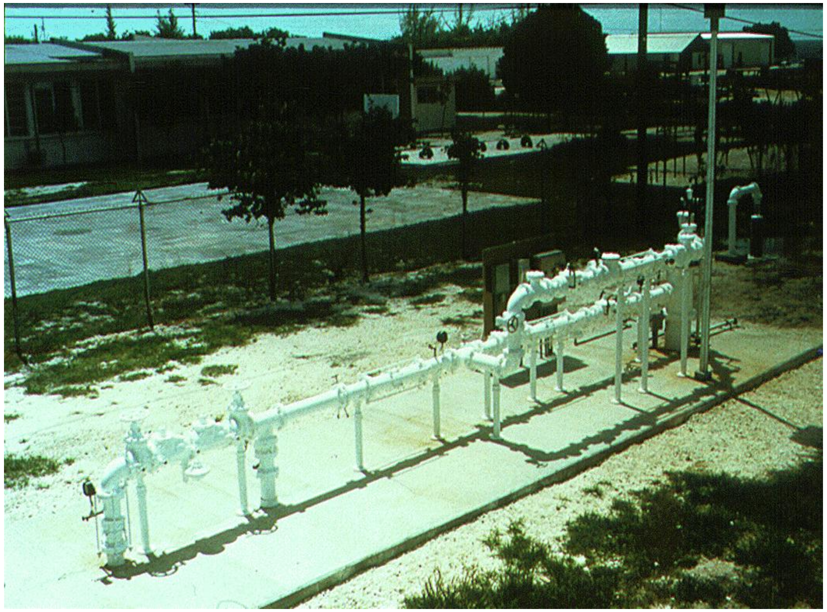
Approximately 33%

Approximately 3%

The rest of the story

Does the existing permit status tell the whole story? Examples from FKAA Marathon and Fort Lauderdale Fiveash WTP ASR

Lake Okeechobee L-63N



FKAA Marathon

Hazen

FKAA Marathon ASR Project

AQUIFER STORAGE RECOVERY
FEASIBILITY INVESTIGATION

PHASE TWO:
EVALUATION OF POTENTIAL
AQUIFER STORAGE/RECOVERY
ZONES

Prepared for
Florida Keys Aqueduct Authority

Prepared by
CH2M HILL

April, 1989
SEF19915.W1

ENGINEERING REPORT
on the Preliminary Results of the

FLORIDA KEYS
AQUIFER STORAGE
RECOVERY TEST PROGRAM
AT MARATHON

For The
FLORIDA KEYS AQUEDUCT AUTHORITY
Key West, Florida

Prepared by
CH2M HILL

SEF19915.W3
AUGUST 1991

FLORIDA KEYS
AQUEDUCT
AUTHORITY

MARATHON

ASR CYCLE
TESTING

Mike Peifer

Project location ideal for emergency water supply

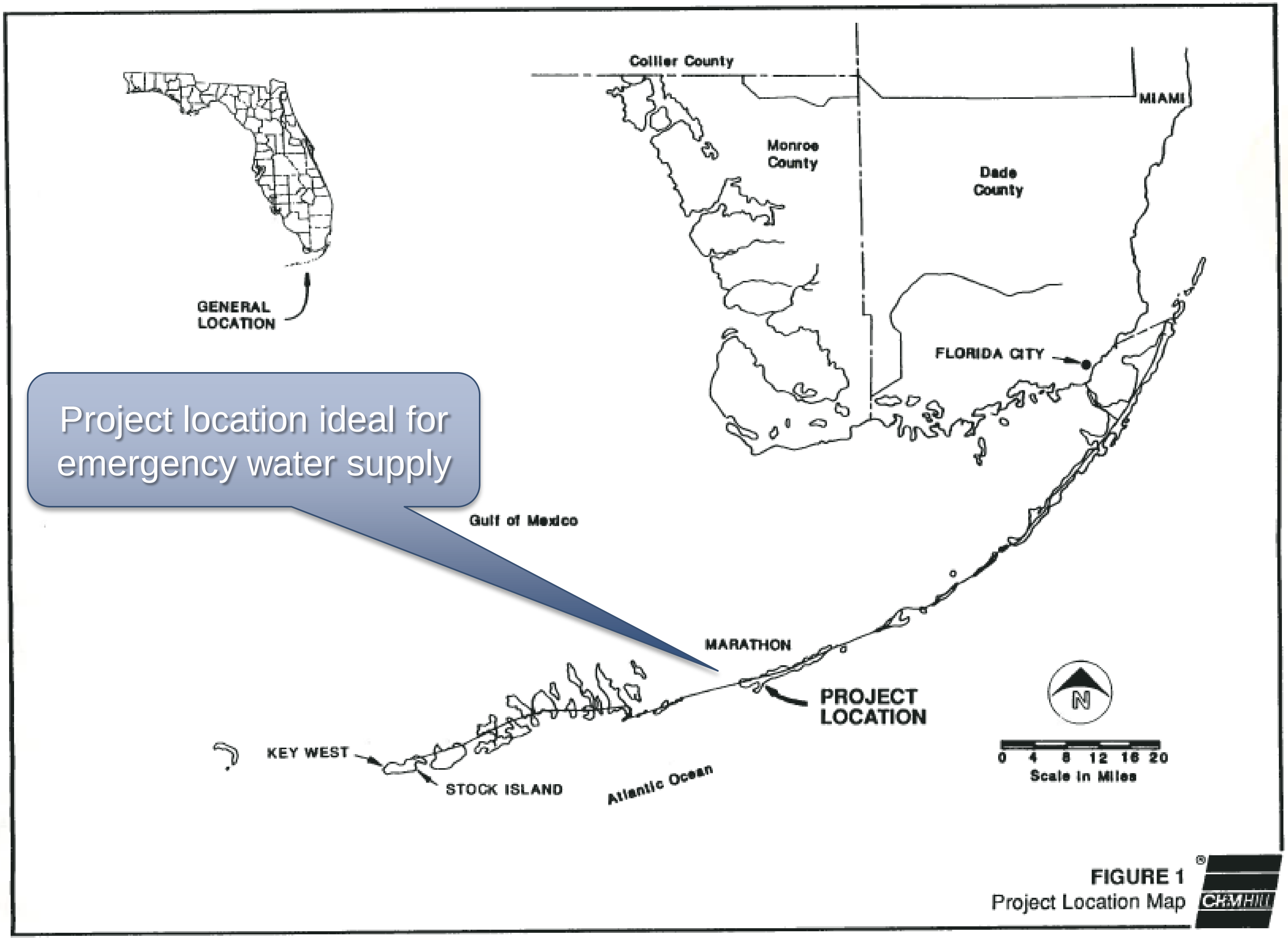
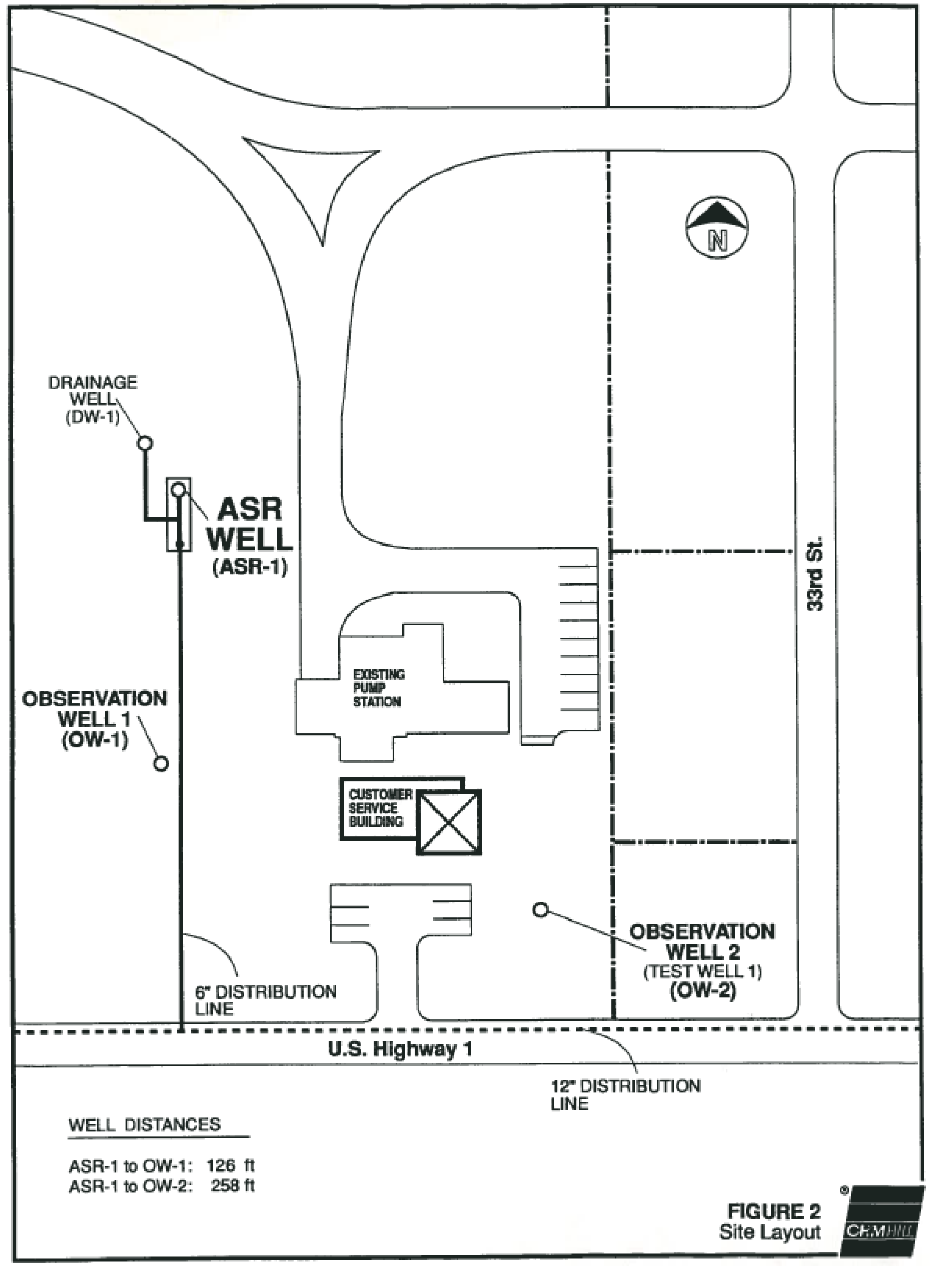


FIGURE 1
Project Location Map

Yes, the project did exist…



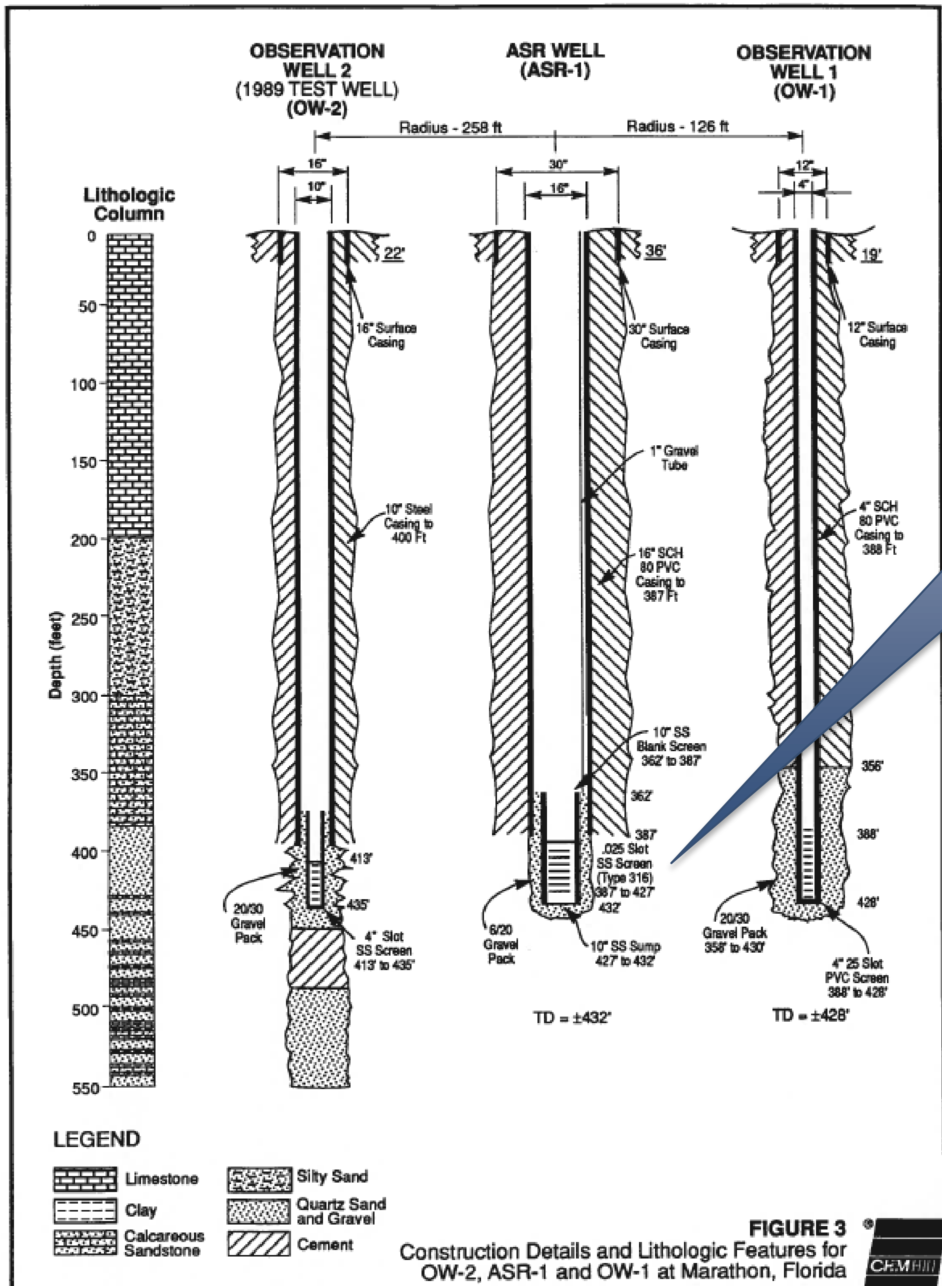


FIGURE 3
Construction Details and Lithologic Features for OW-2, ASR-1 and OW-1 at Marathon, Florida

Well screened from 387 to 427 feet

Well constructed over a 40 foot horizon with excellent overlying and underlying confinement

Table 4
Physical Properties and Chemical Characteristics of Injected and Native Waters
FKAA ASR at Marathon, Florida

Constituent	Injected Water (mg/l)	Native Water (mg/l)
pH	10.3	7.60
Total Alkalinity	23.1	120
Conductivity (µmhos/cm)	397	49,000
Carbonate Hardness	110	1,390
Non-carbonate Hardness	95.0	6,480
Turbidity (NTU)	<0.2	<0.2
Total Dissolved Solids	212	37,200
Total Suspended Solids	<1.0	4.2
Calcium	33.8	398
Magnesium	3.75	1,250
Sodium	20	11,000
Potassium	11.4	385
Silica	4.7	9.43
Aluminum	<0.5	<0.5
Iron	0.05	<1.0
Chloride	41.8	20,800
Fluoride	0.80	0.84
Sulfate	91.1	2,910
Nitrate and Nitrite	<0.02	<0.02
Carbonate	16.8	0
Bicarbonate	23.1	146

Note: Injected water sampled April 3, 1990
Native water sampled May 4, 1990

dbt004\112.51

Conductivity
49,000

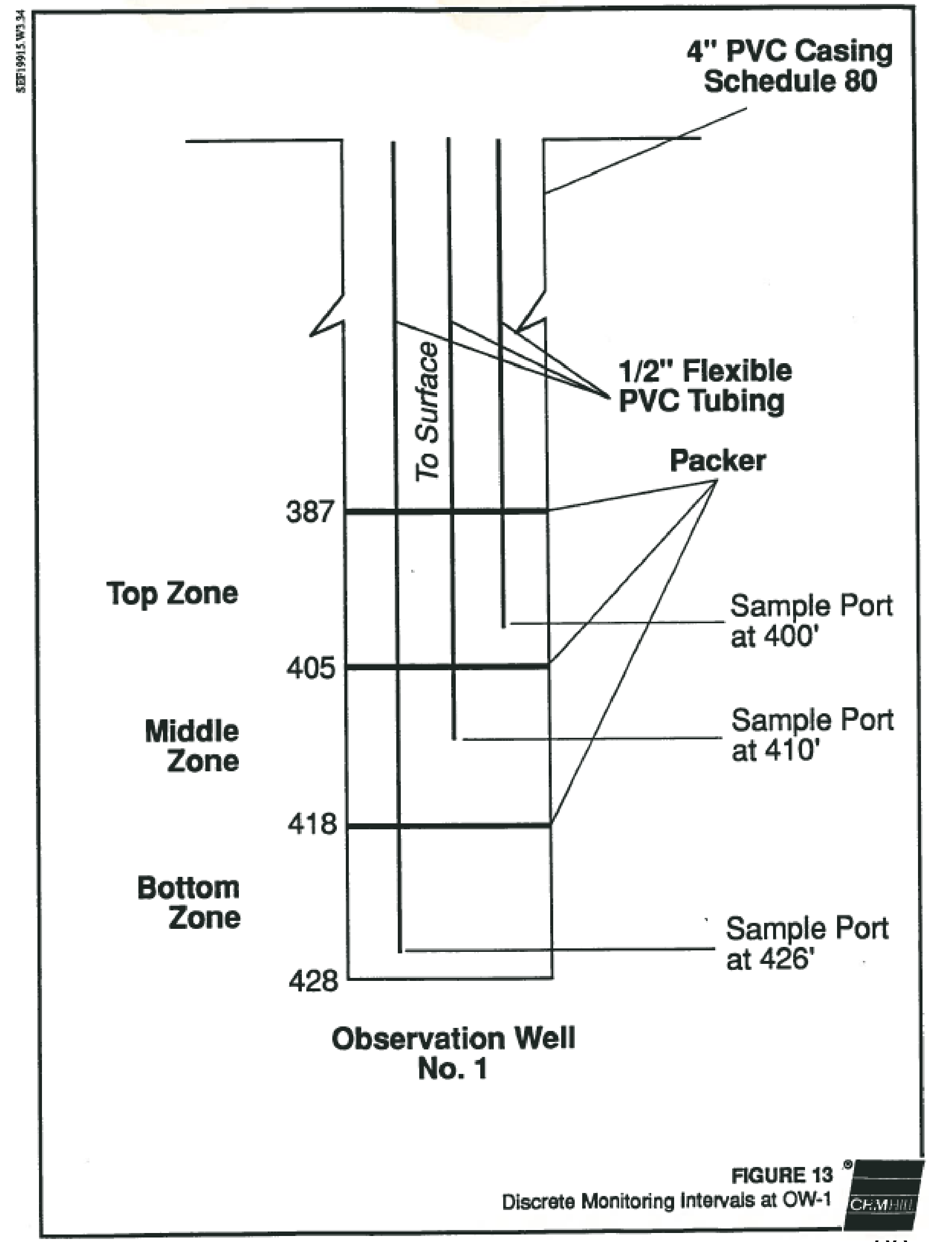
Total Dissolved Solids
37,200

Storage zone water quality was similar to seawater

Chloride
20,800

Unique testing

Three probes were installed to monitor the movement of the injected fluids to estimate the shape of the "bubble"



Hazen

SEF19915.W3.34

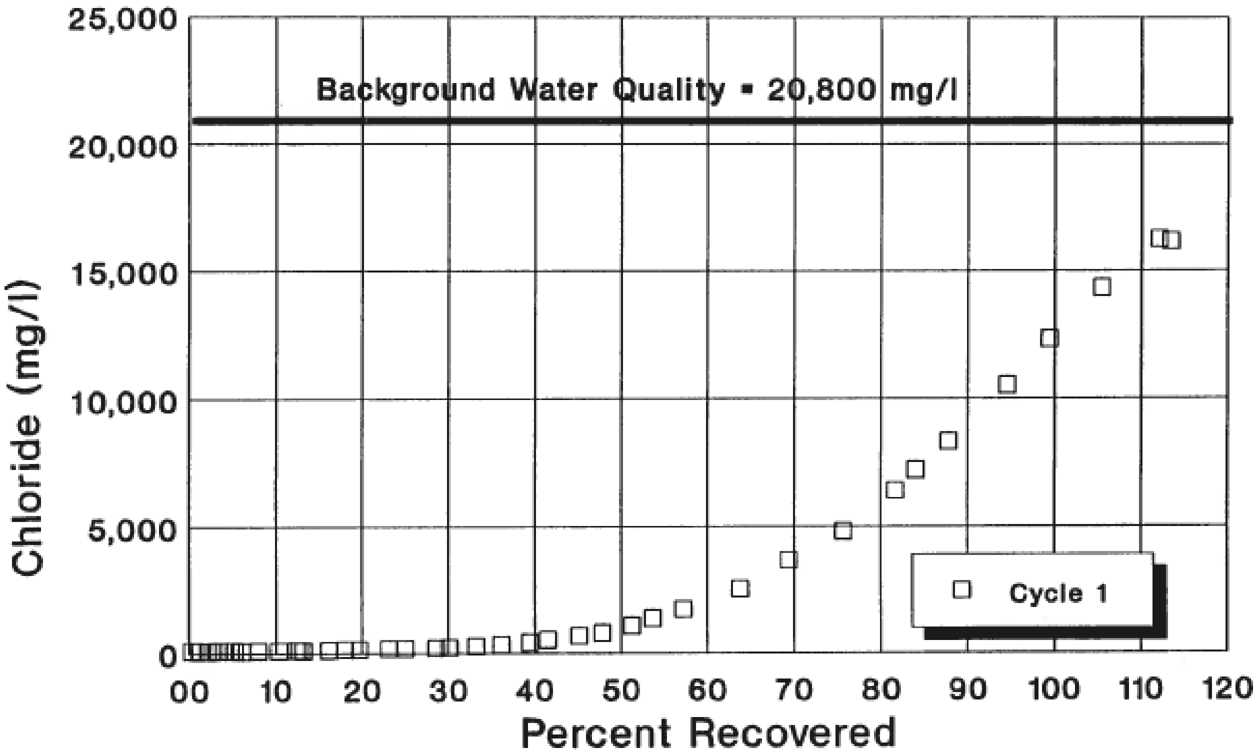
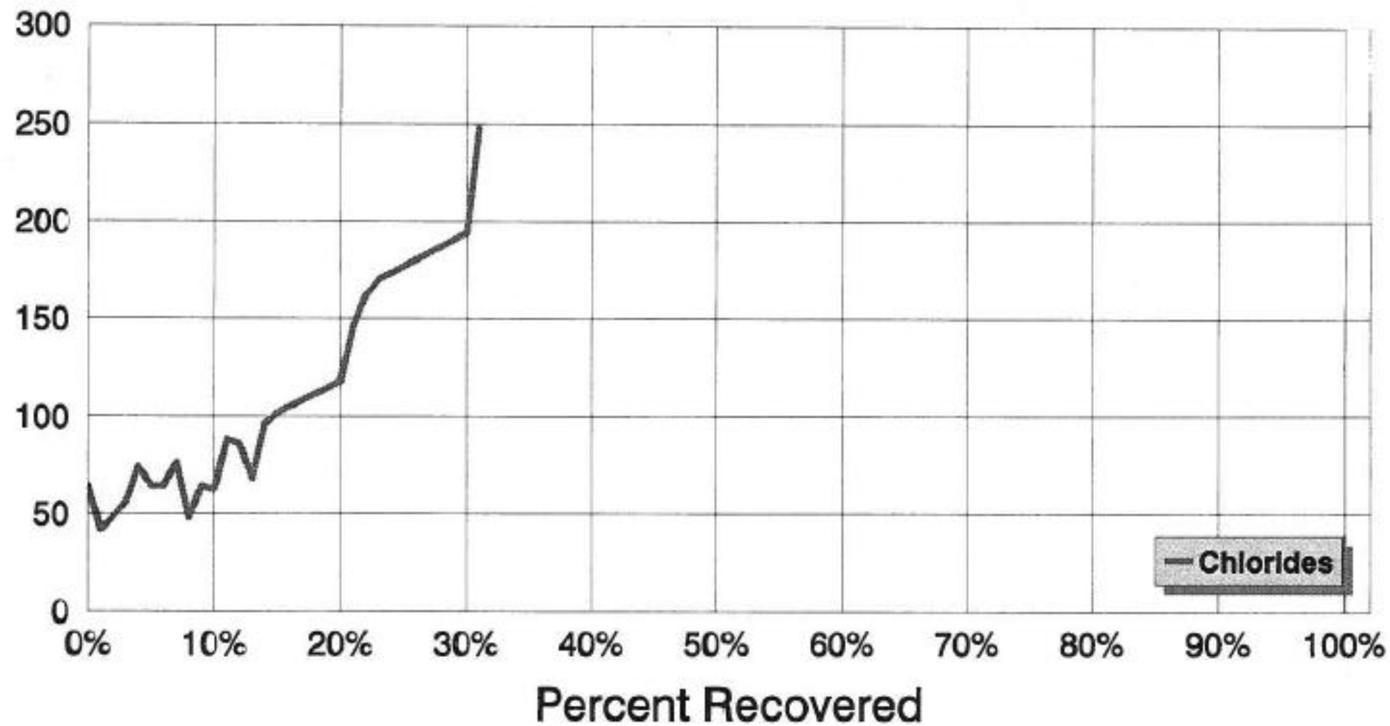


FIGURE 14
Chloride Concentration vs Percent Recovered for Cycle 1

CH2M HILL

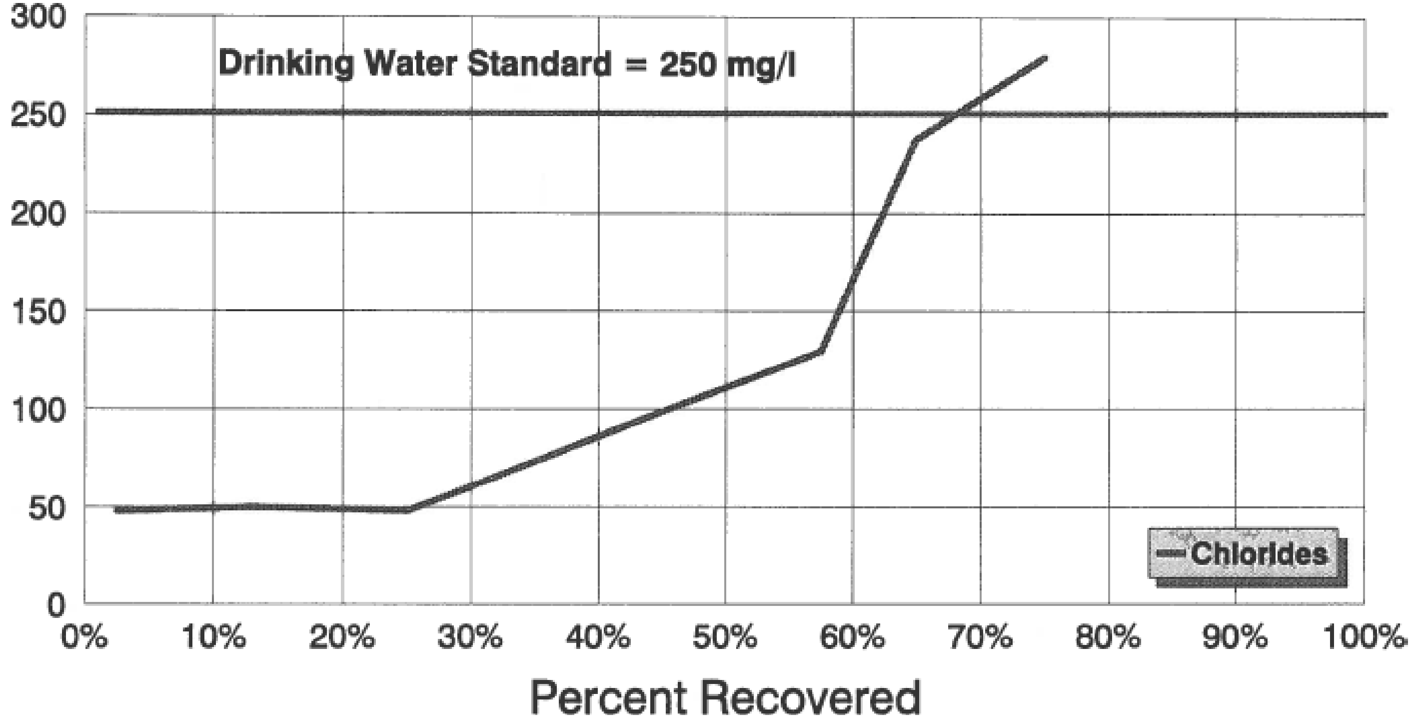
Florida Keys Aqueduct Authority

Cycle1 Recovery



Florida Keys Aqueduct Authority

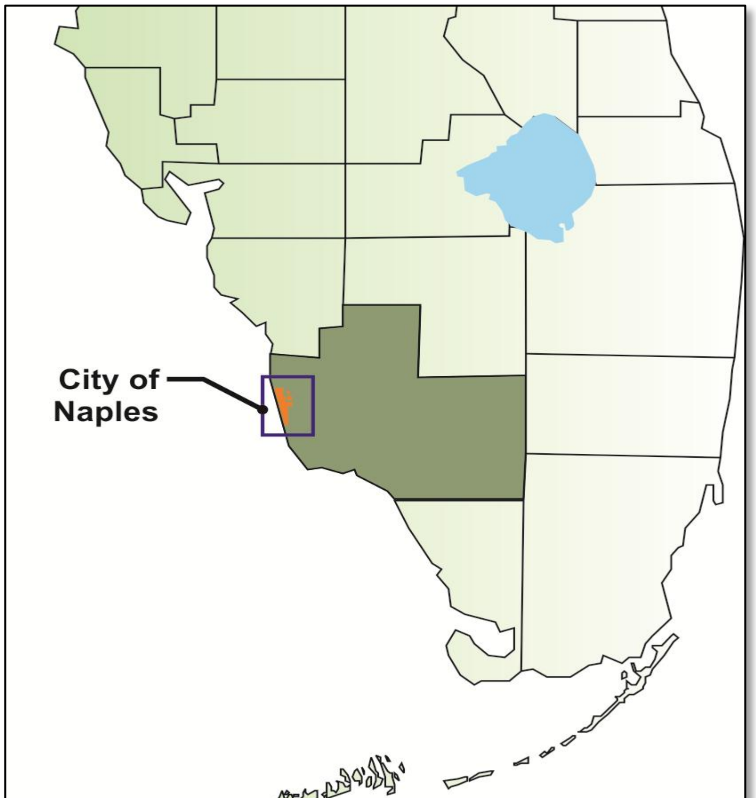
Cycle 4 Recovery

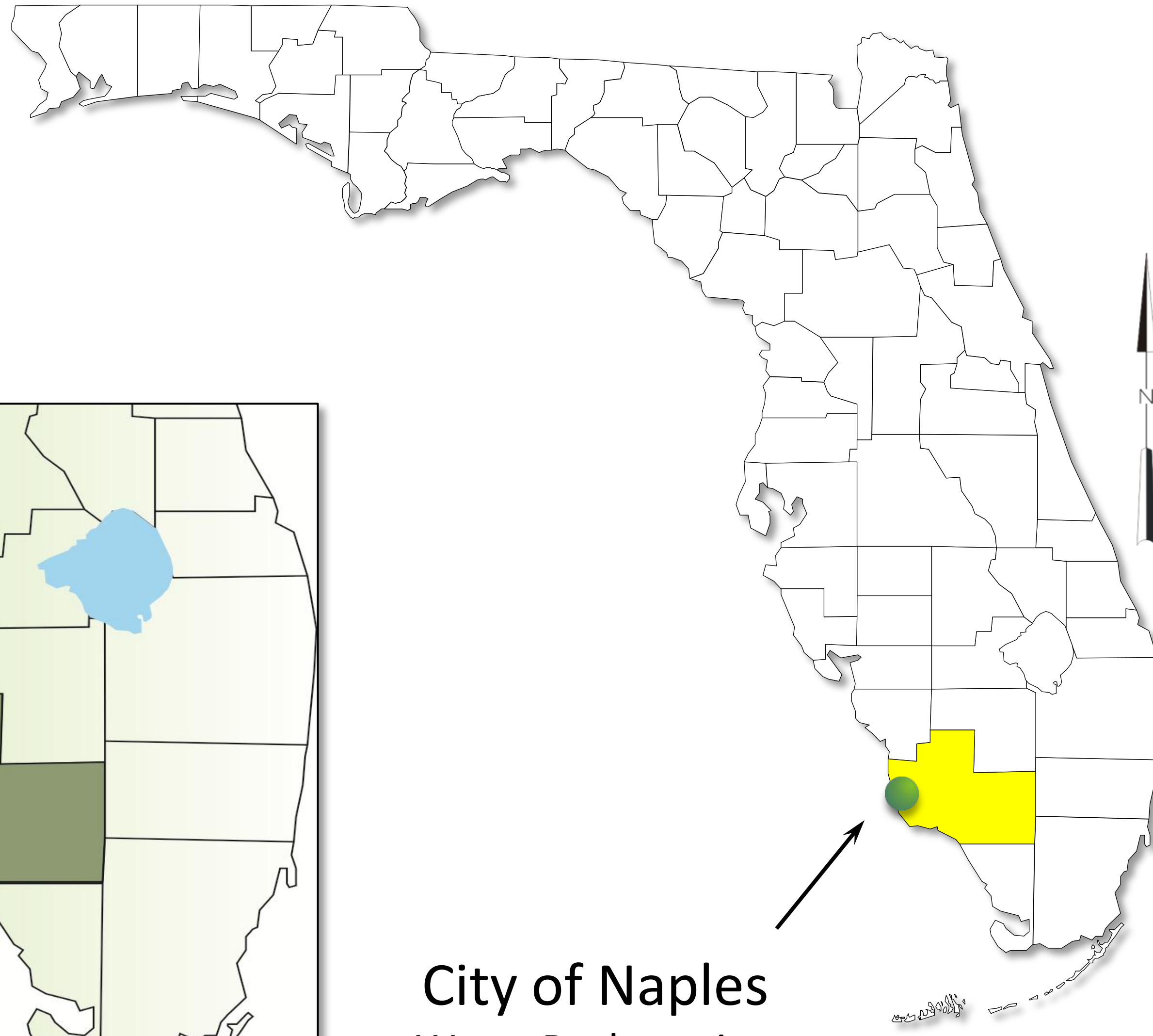


The Naples ASR system

Storing reclaimed and / or surface water in a brackish to saline environment

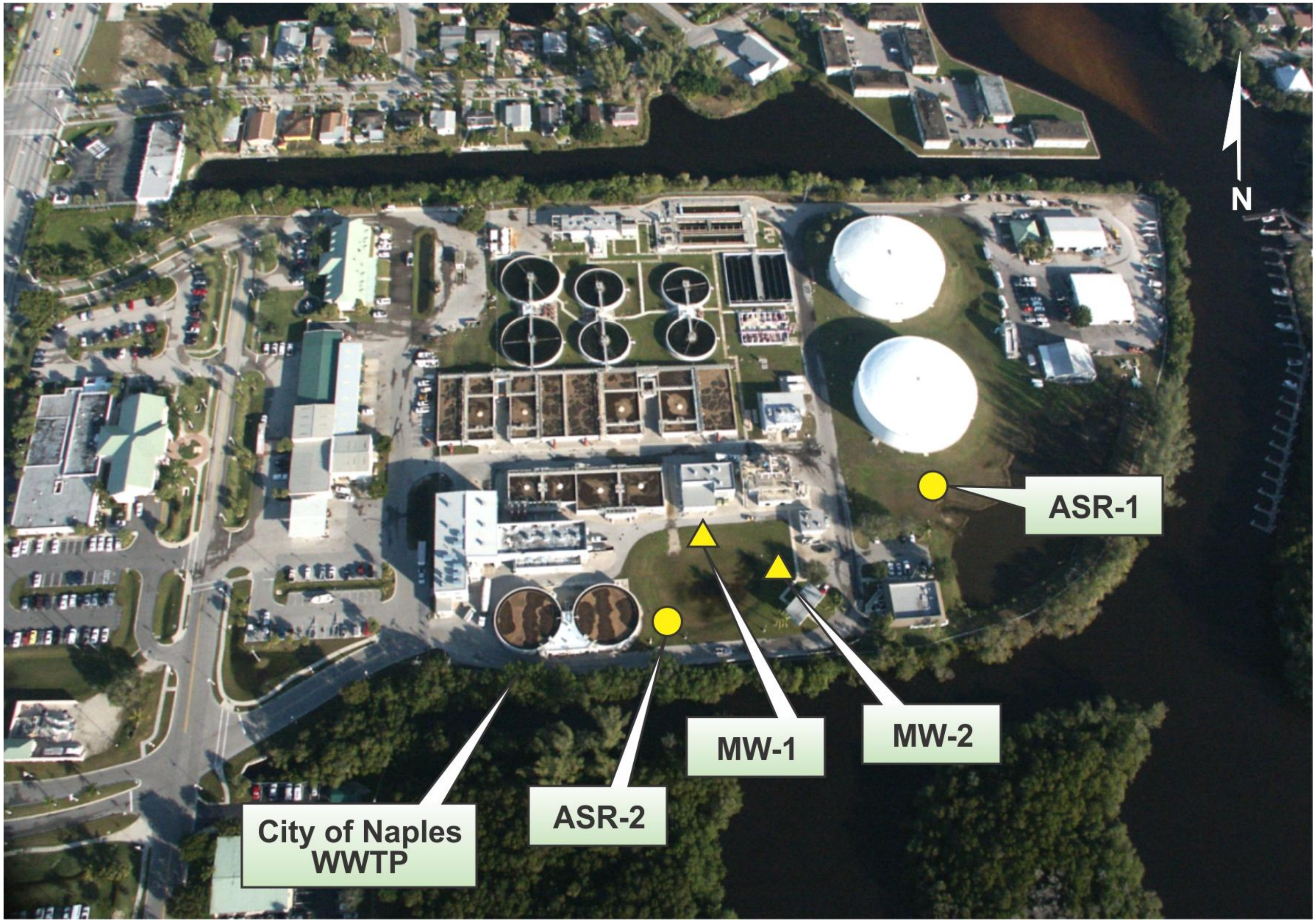
General location map





City of Naples
Water Reclamation
Facility

City of Naples
Water Reclamation Facility site layout

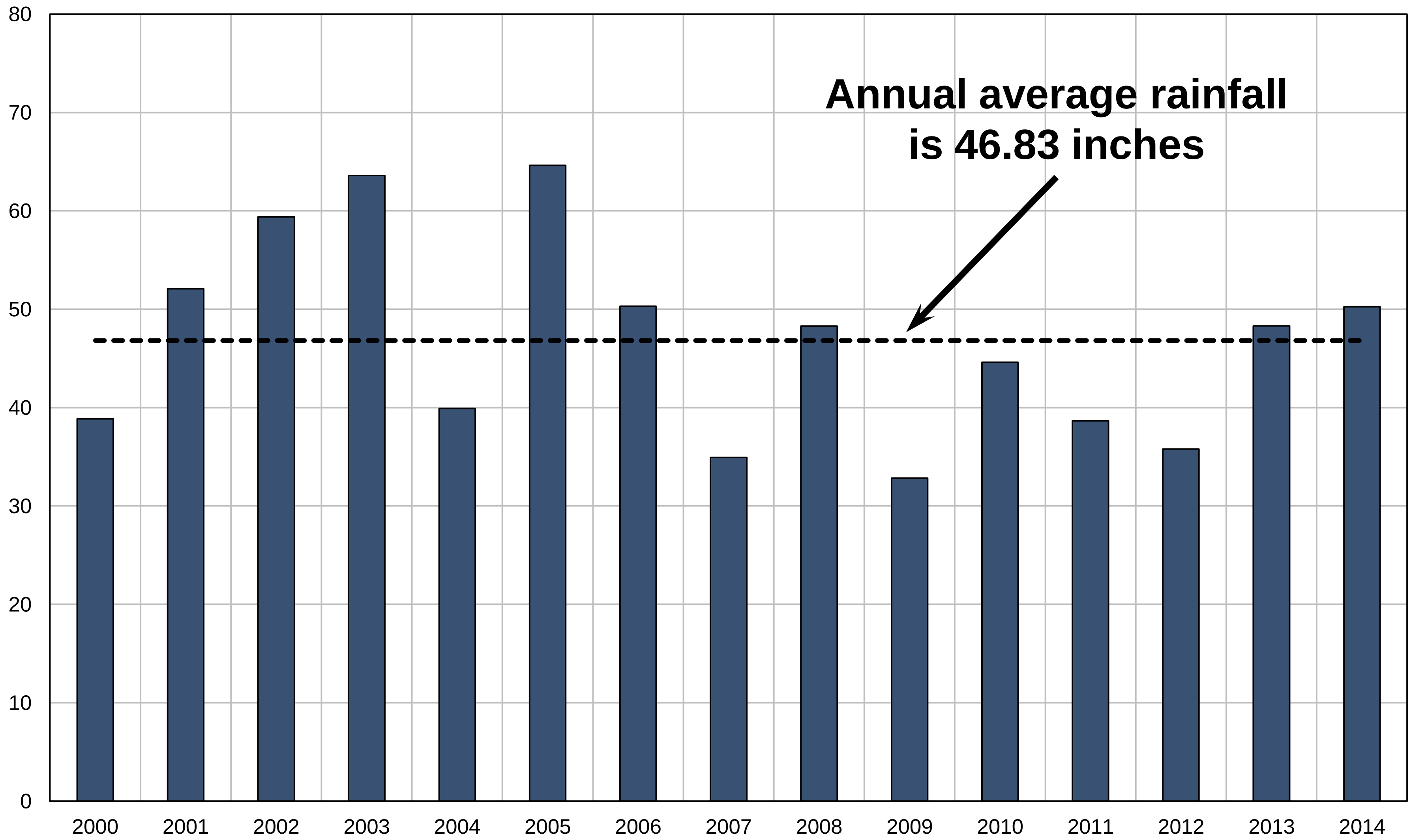


Benefits of implementing ASR

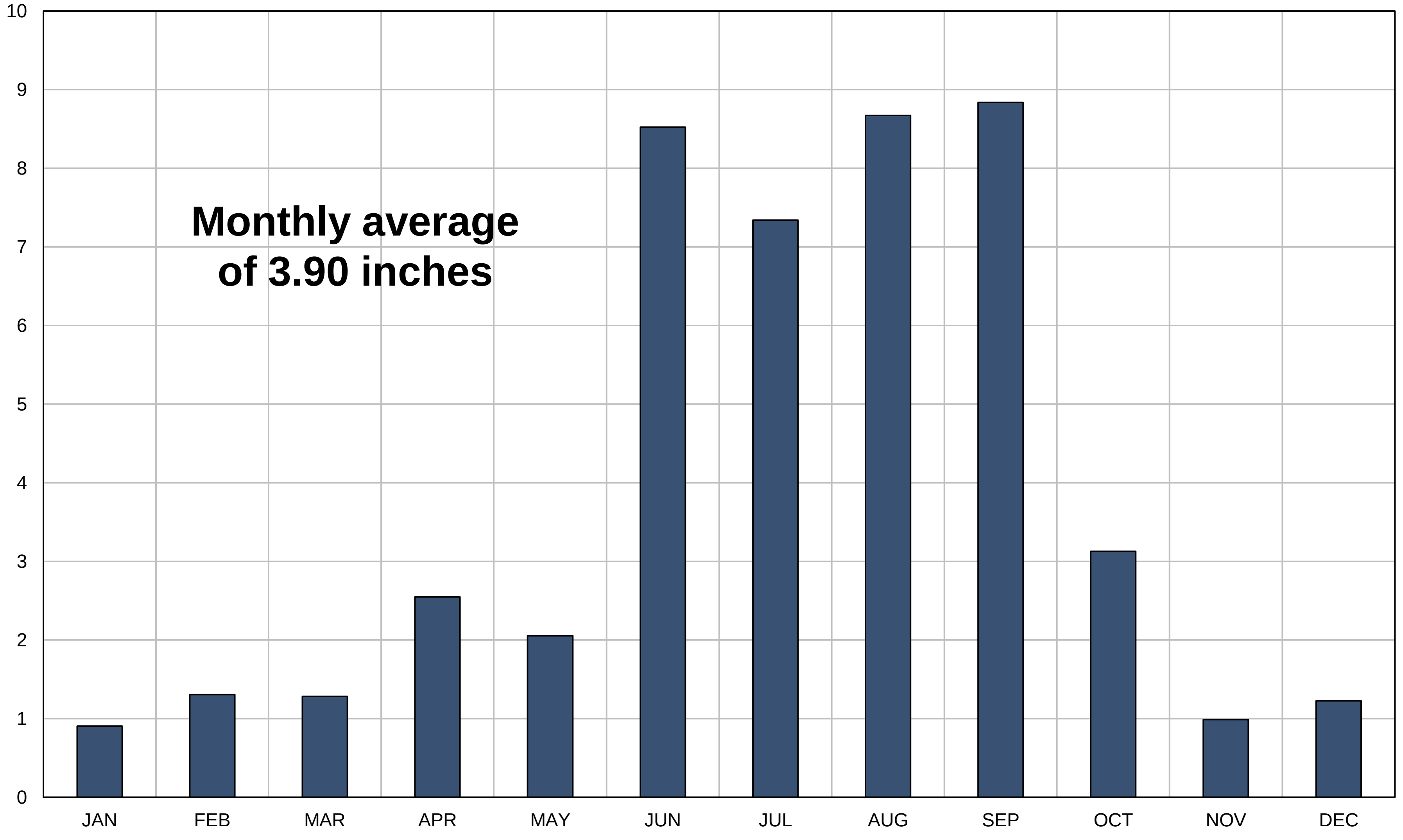
Implementation of the reclaimed water / surface water ASR system affords the City of Naples the following:

- Reduce potable water demands
- Extend the useful life of the City's raw water supply
- Extend the useful life of the City's water treatment facility
- Maximize use of reclaimed water
- Provide additional wet weather storage
- Optimize use of excess surface water from Golden Gate Canal
- Reduce and virtually eliminate surface discharge to Naples Bay
- Reduce run-off to the estuary from Golden Gate Canal

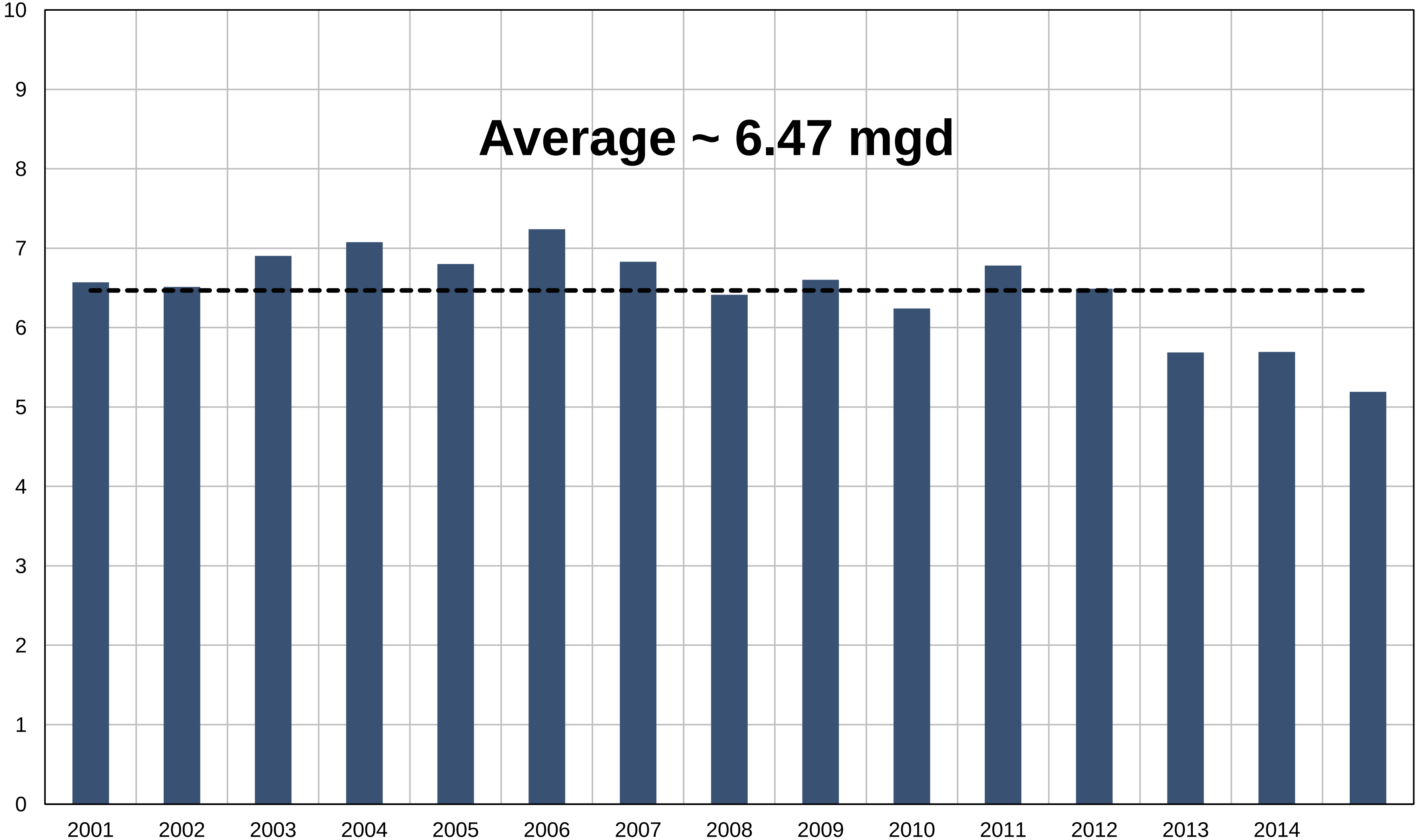
Historical annual rainfall from 2000 thru 2014



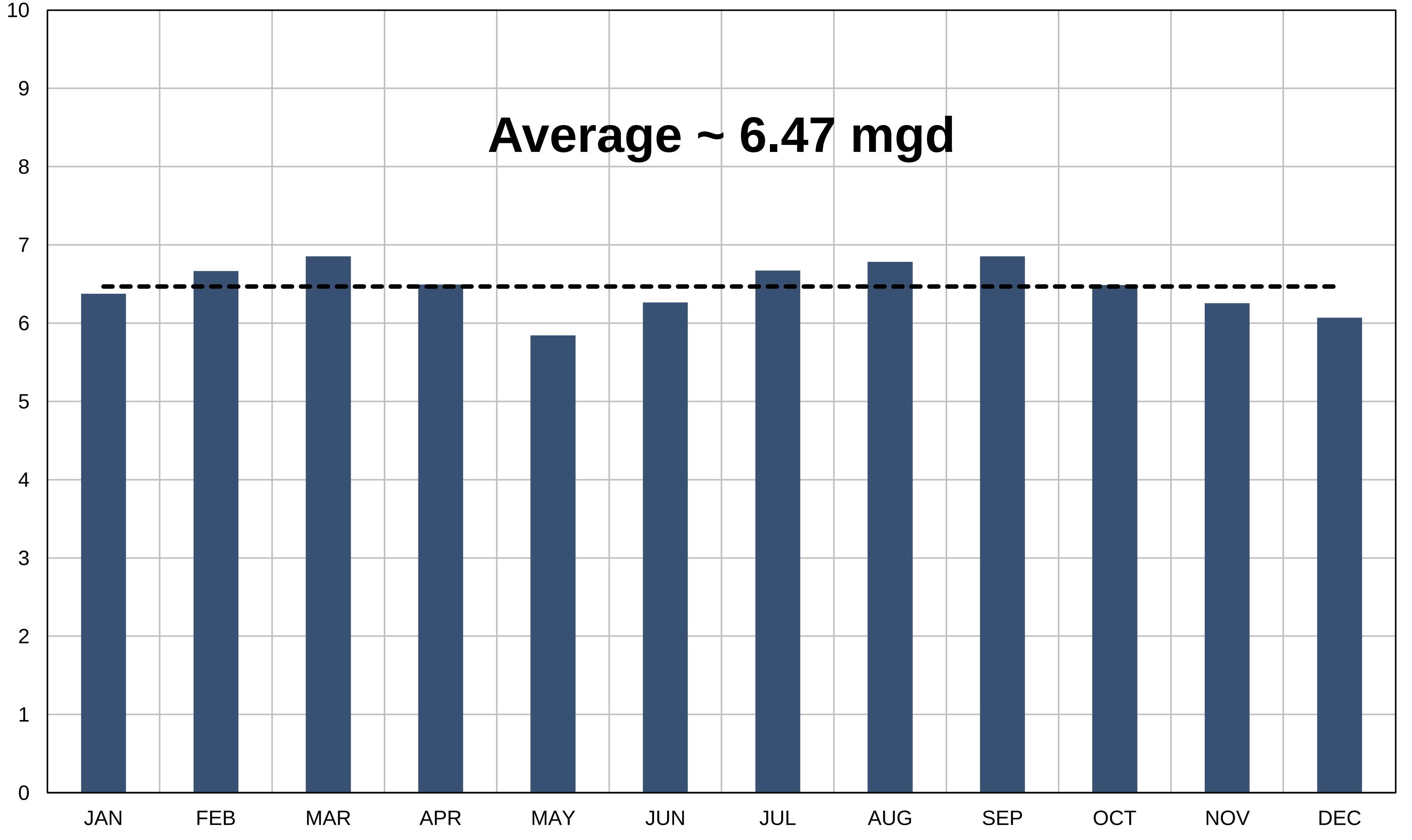
Fifteen year period of record show typical rainfall pattern for South Florida



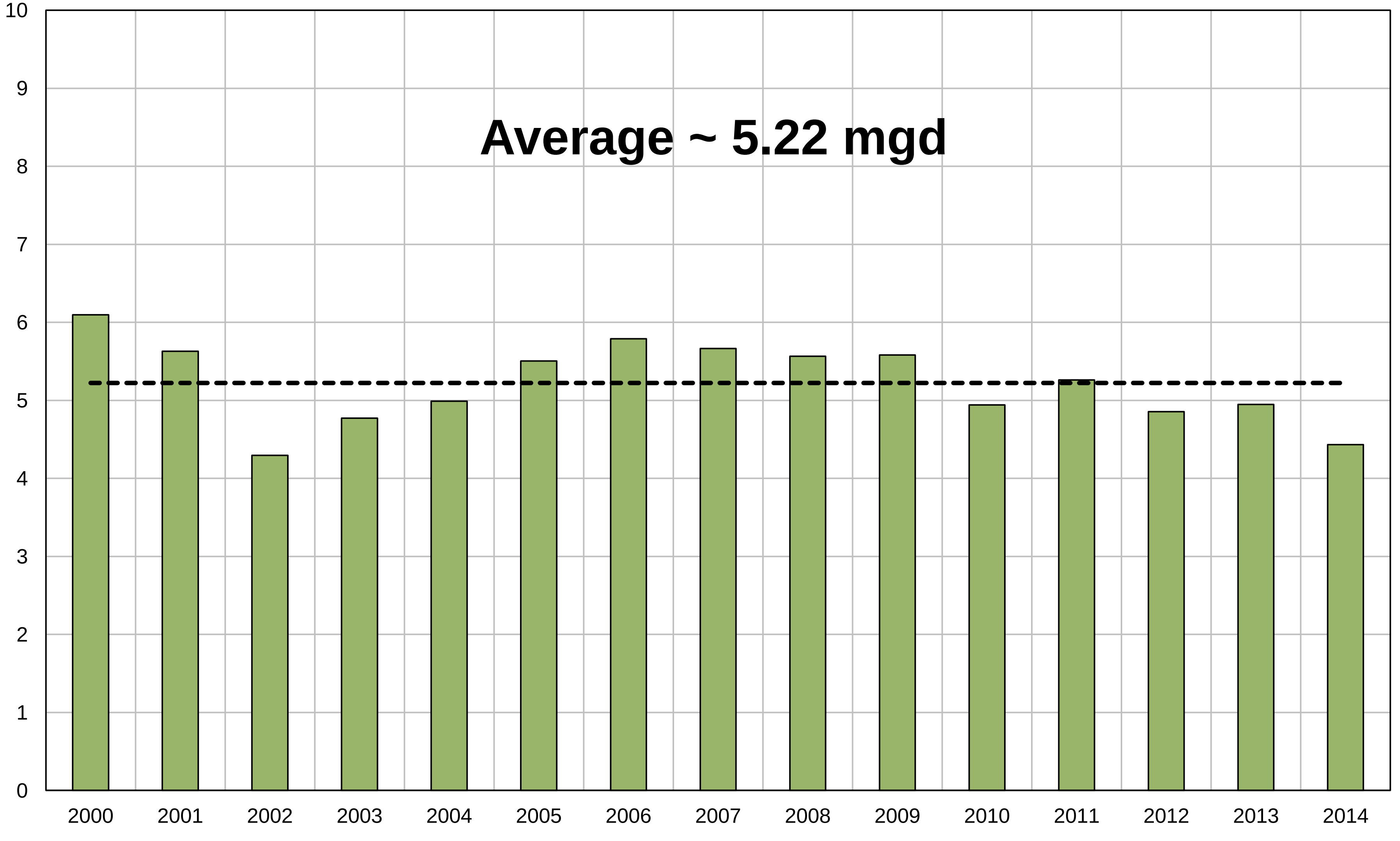
Historical annual wastewater flows have decreased slightly during the past few years



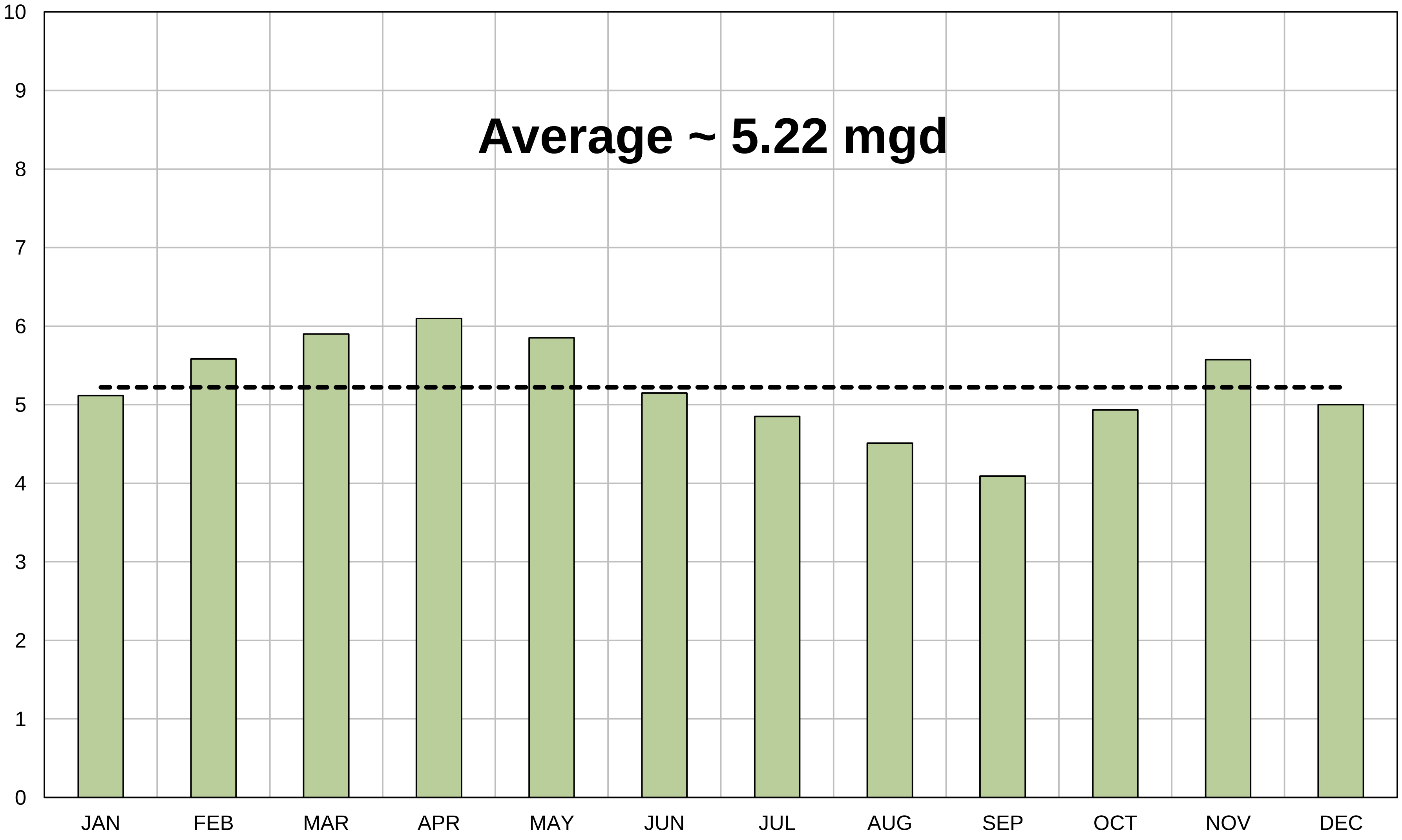
Historical monthly wastewater flows have remained fairly consistent



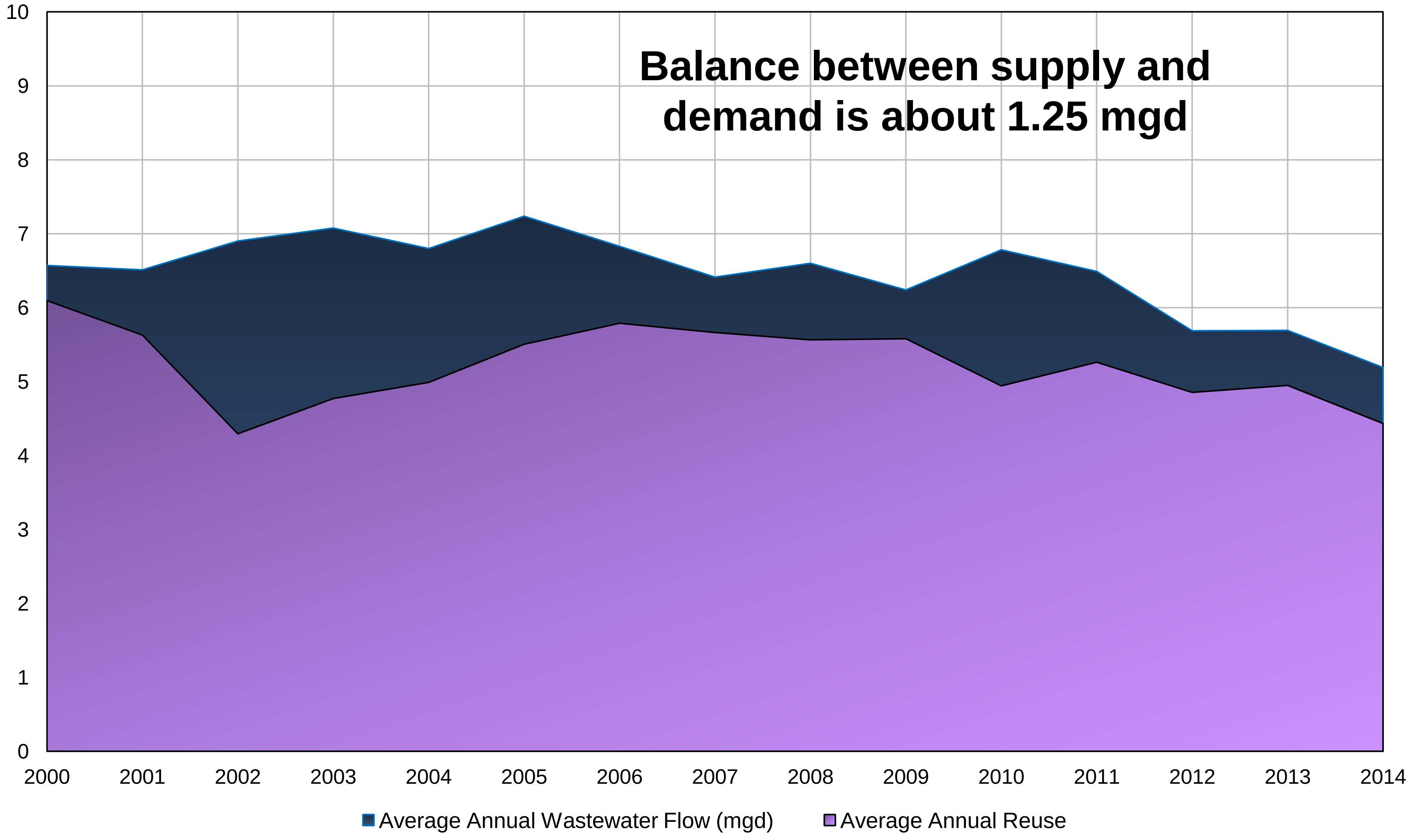
Historical annual reuse flows have trended similar to wastewater production



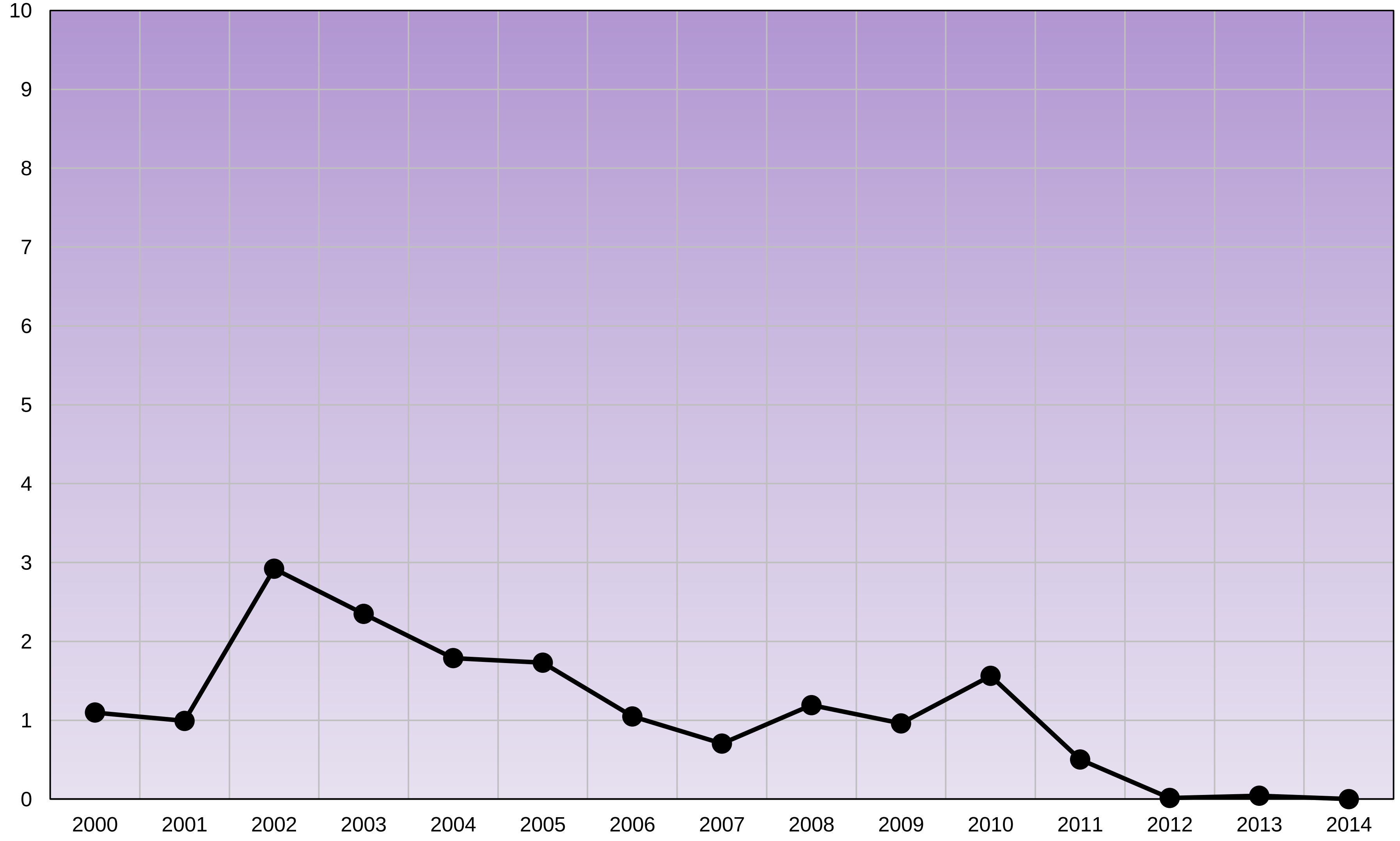
Historical monthly reuse flows show less demand during the wet season



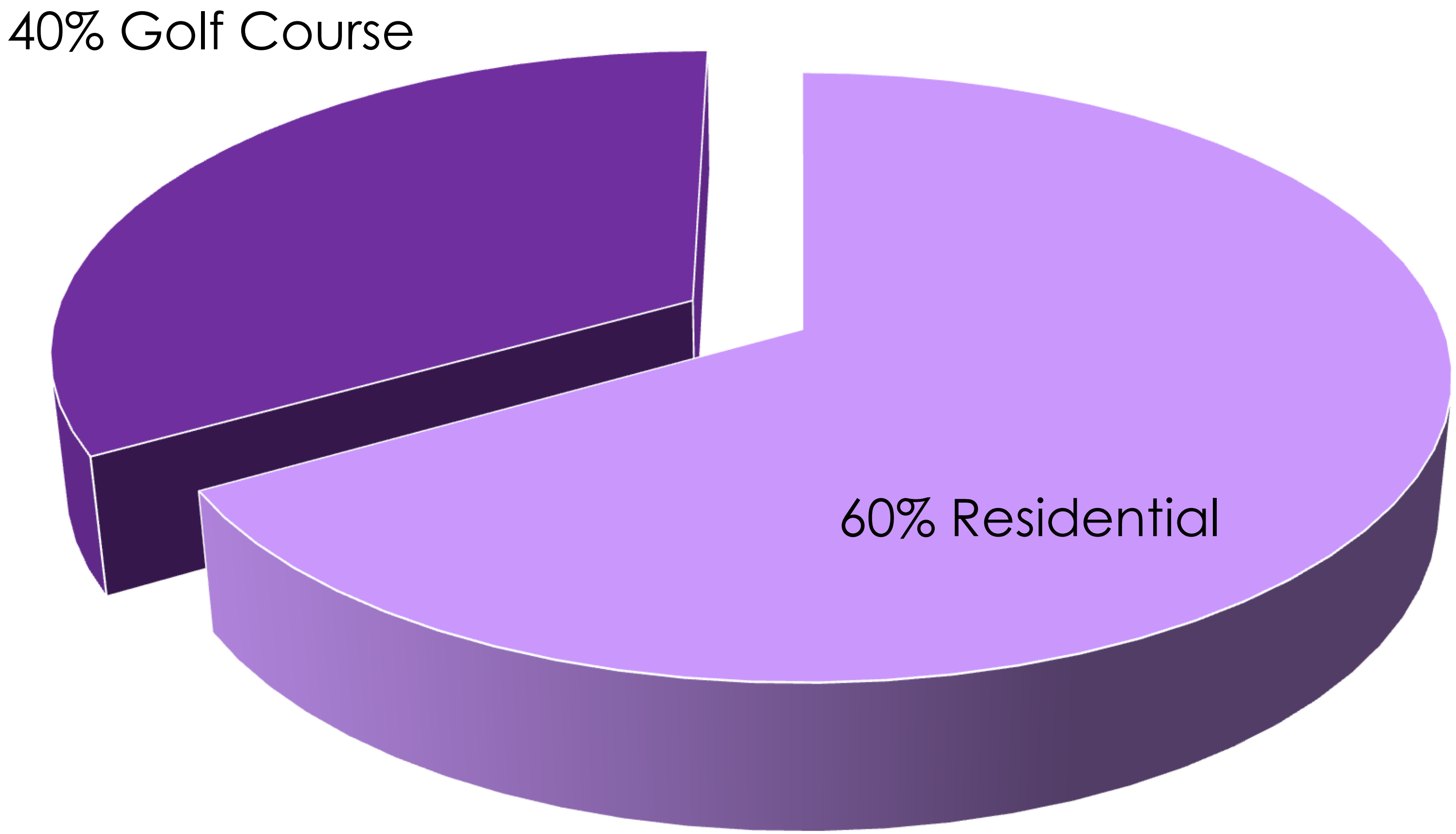
Excess reuse quality water requires wet weather storage



Excess reuse water was historically discharged to surface waters, but now stored via ASR wells



Reuse is popular and provides a cost effective method for effluent management

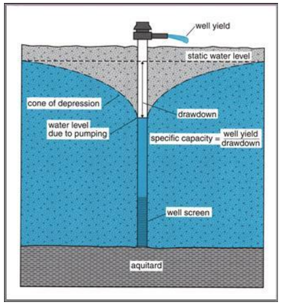


But where to you store the excess?

The historical "urban" hydrologic cycle

Source

- Not a "cycle" on the local level
- Fresh water resources were historically wasted via discharge to the ocean or a deep injection well



Supply Well

Treatment

Water Use

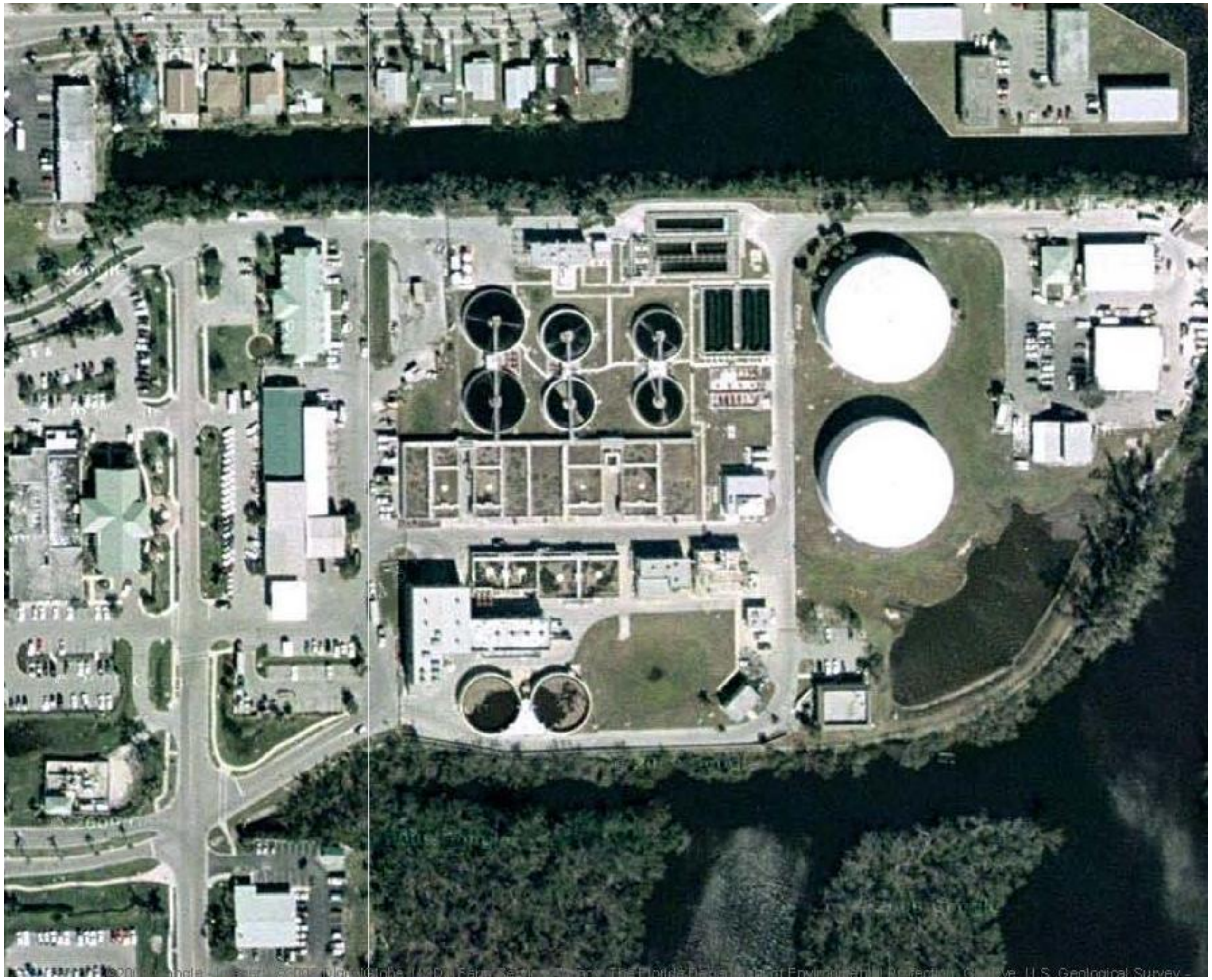
Wastewater Disposal

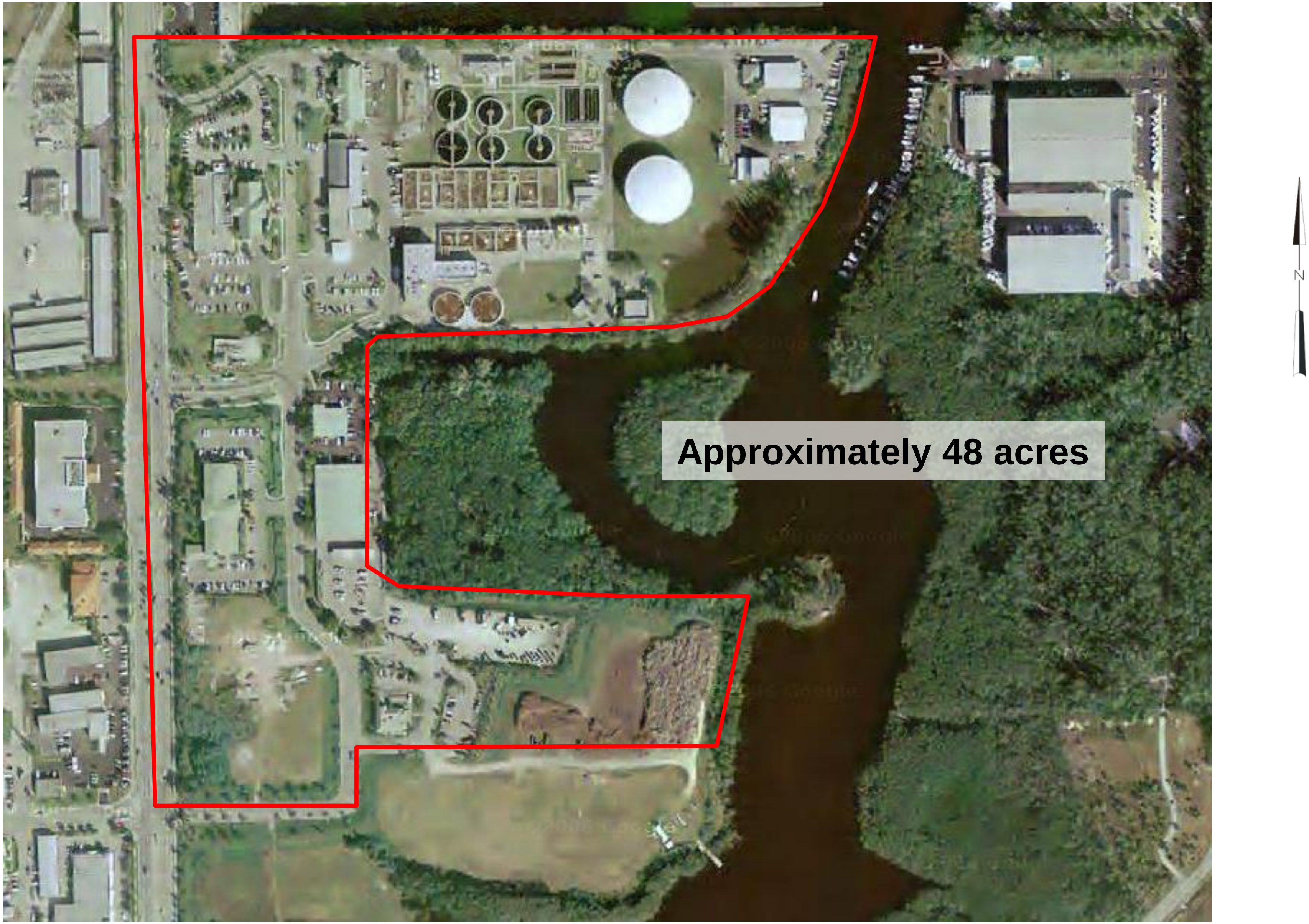
The improved “urban” hydrologic cycle

Where could the reclaimed water go?

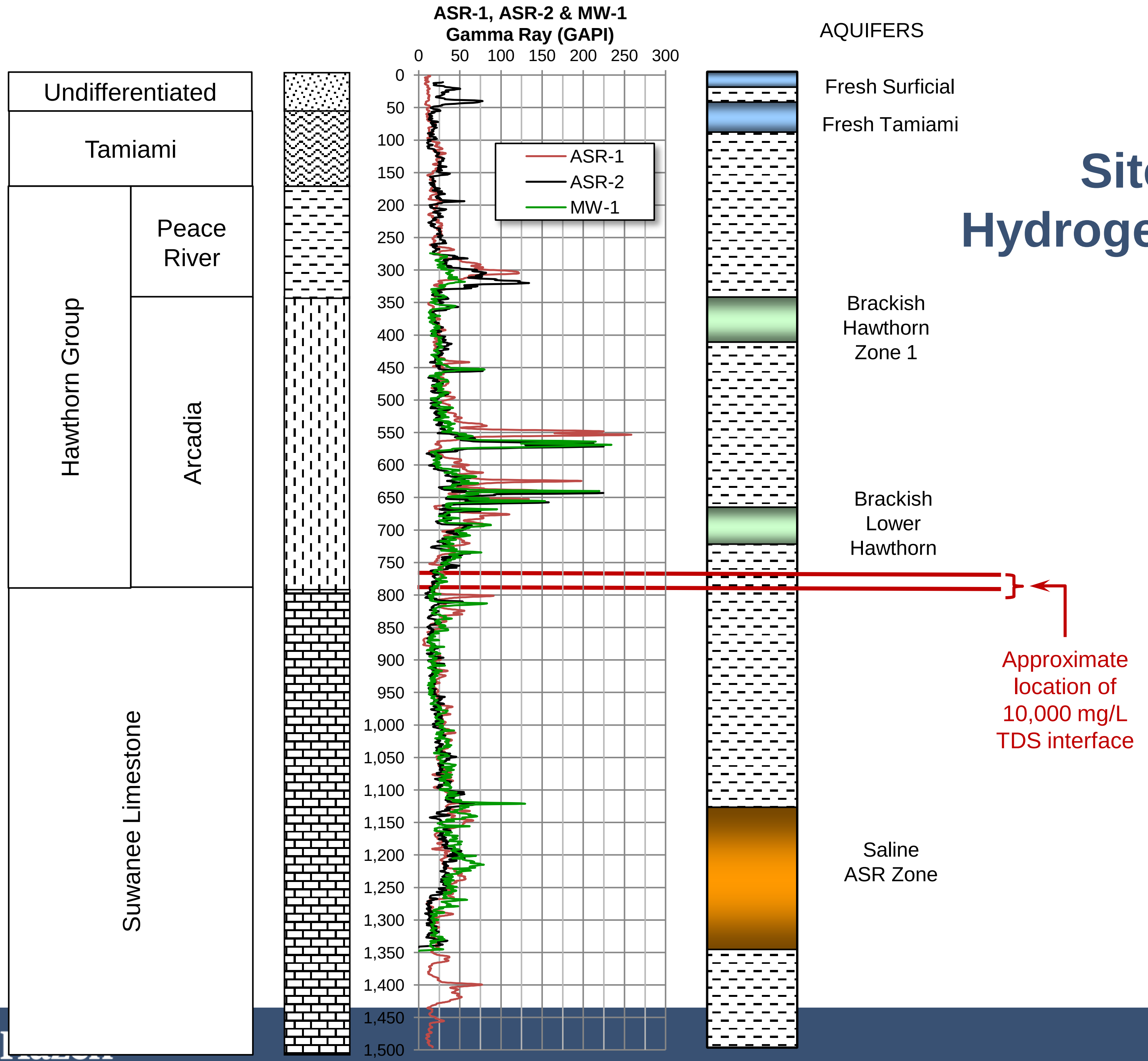
- Land application (**irrigation**, percolation ponds, etc.)
- Ponds, lakes, wetlands
- Subsurface
  - Aquifer storage and recovery
  - Injection / recharge wells
    - Floridan Aquifer
    - Surficial Aquifer

Naples Water Reclamation Facility

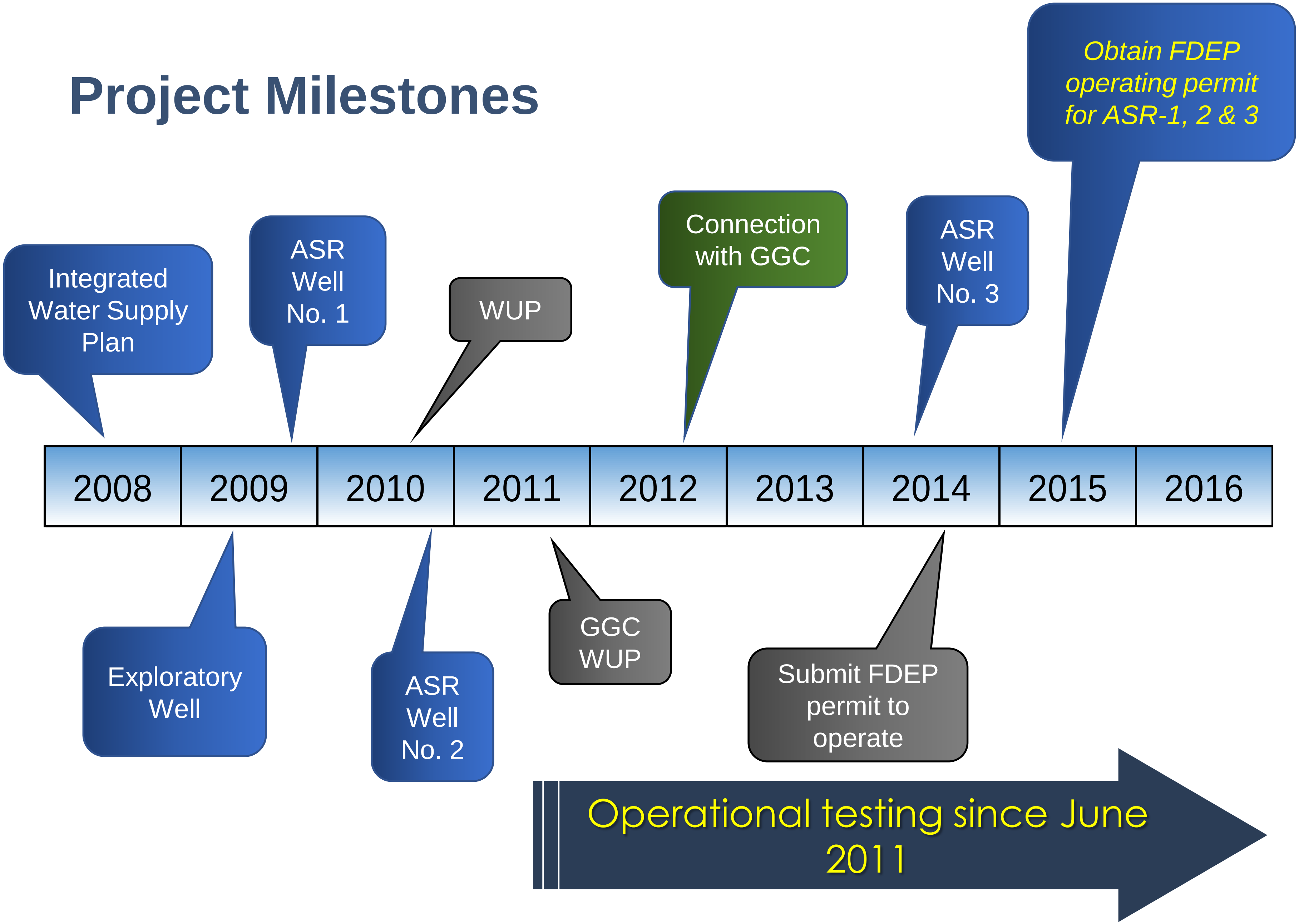



Approximately 48 acres
N

Site Hydrogeology



Project Milestones



Many facilities have been constructed to date

Exploratory Well

Phase 1

ASR Well No. 1

Phase 2

ASR Well No. 2

Monitor Well Nos. 1 & 2

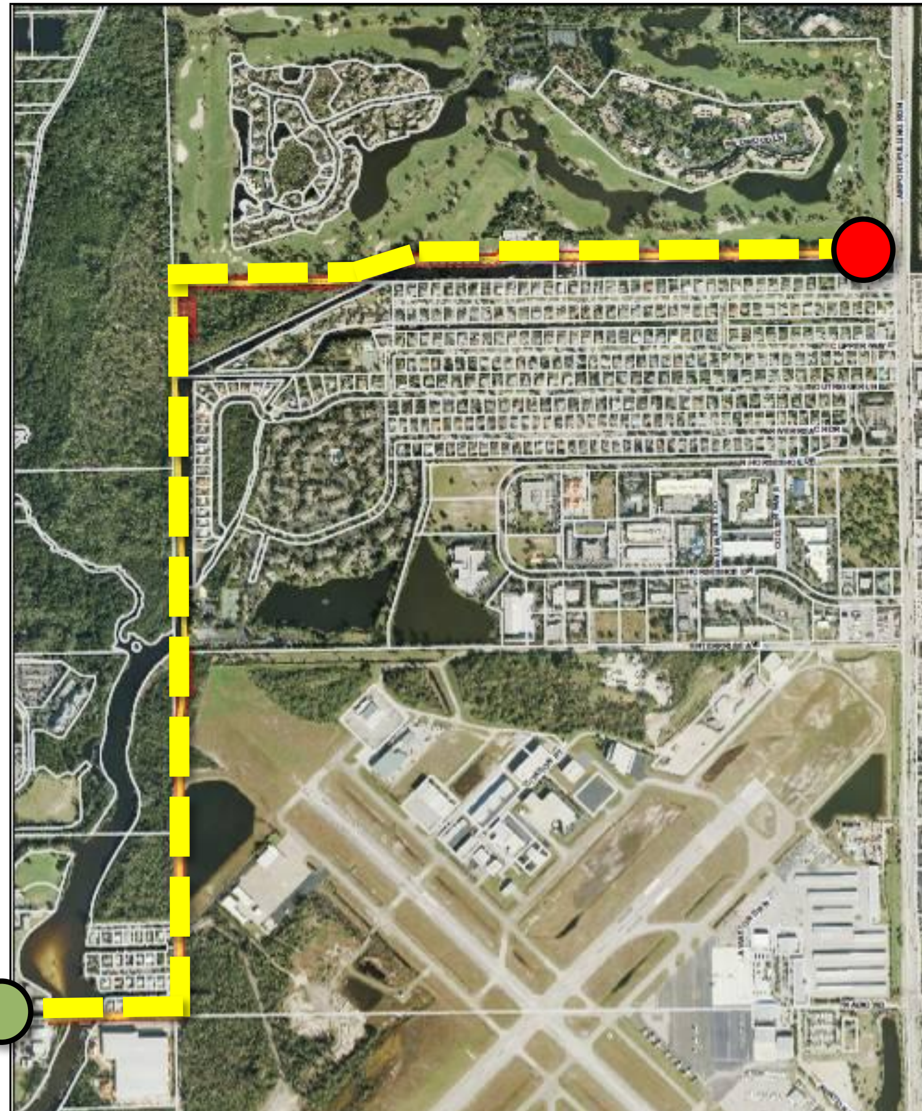
Phase 3

Monitor
Well No. 3

ASR Well No. 3

Construction of surface facilities allowed development of storage zone

Pumping and piping from the Golden Gate Canal provides a back-up source

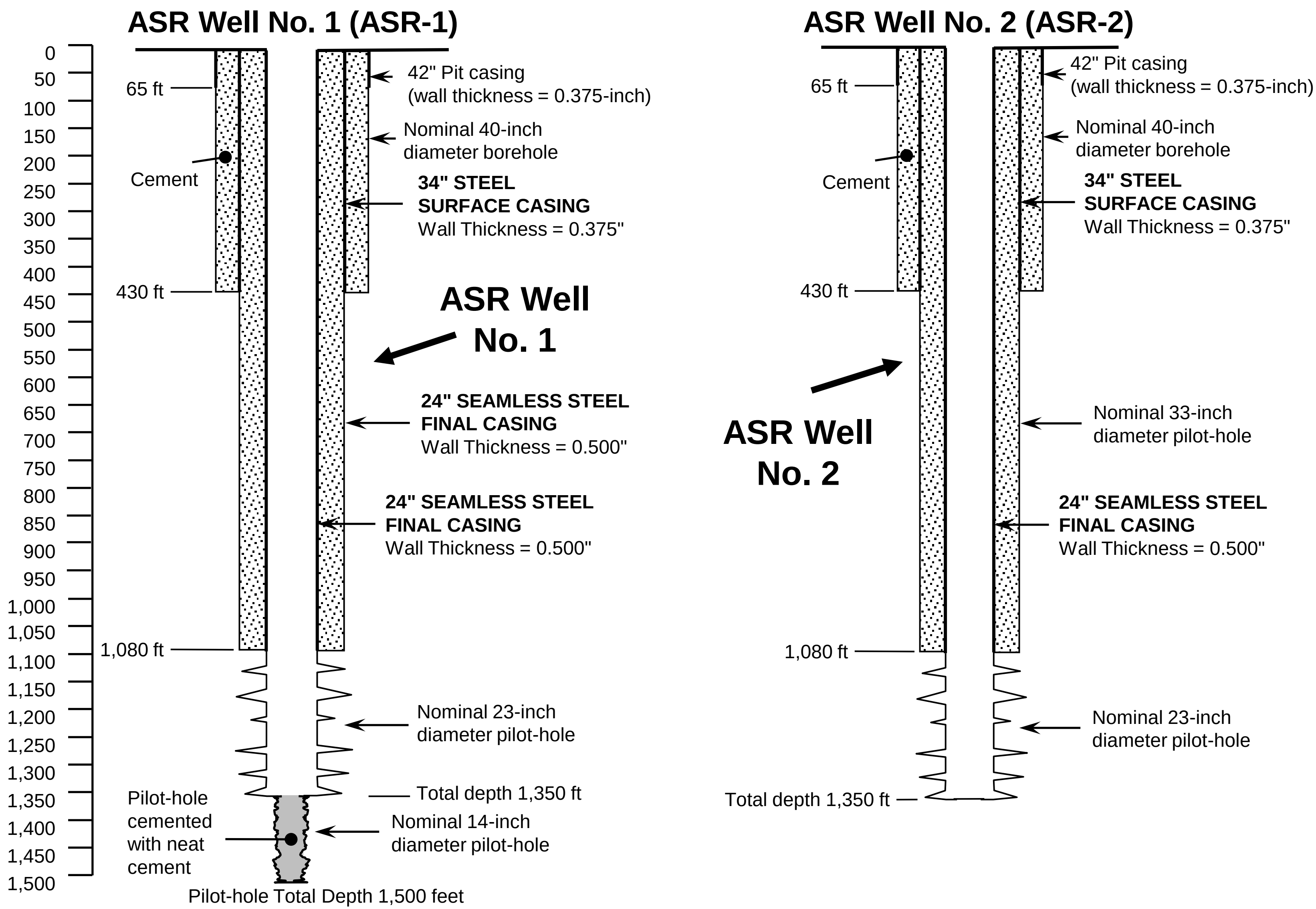


Intake Structure

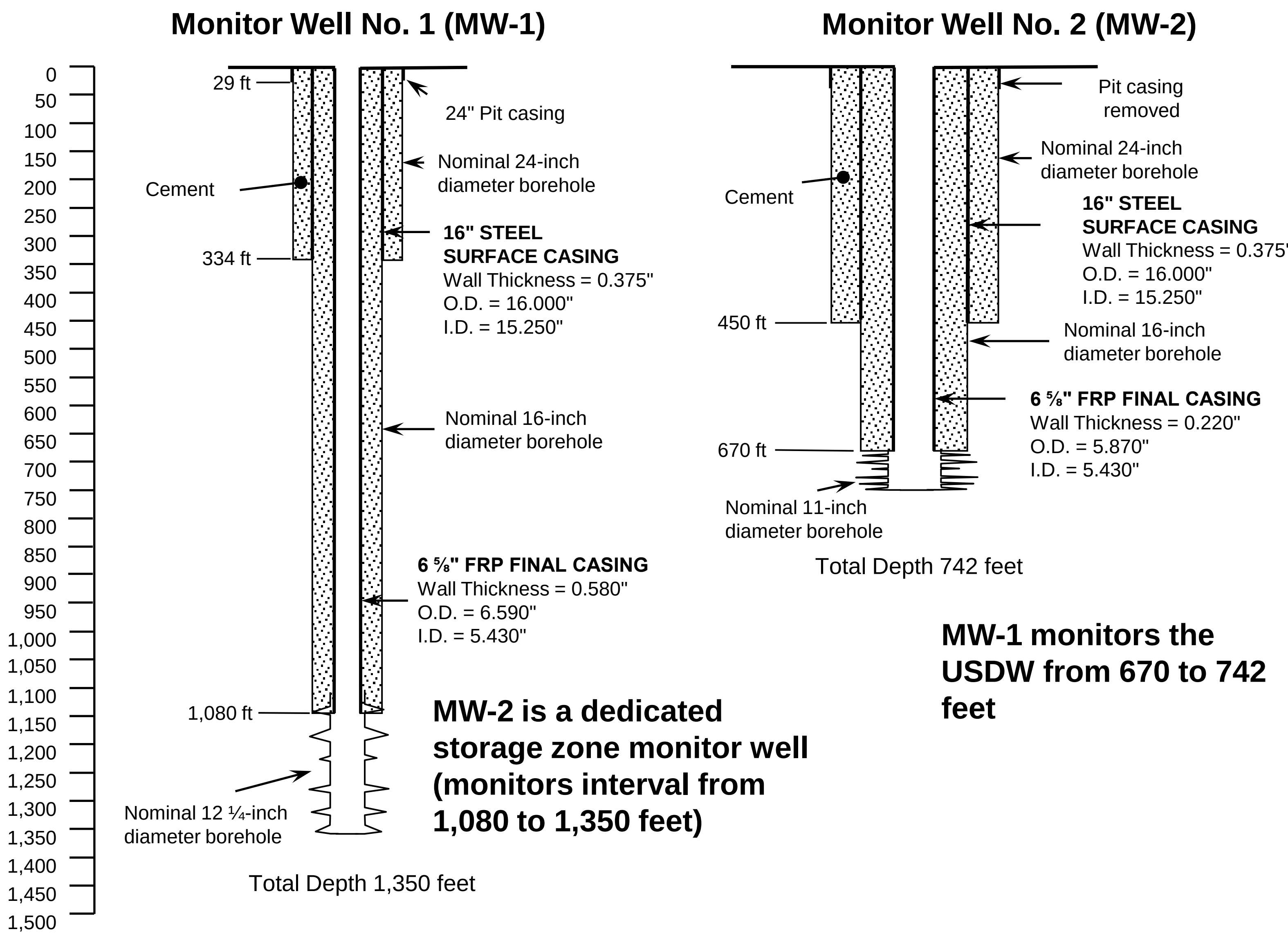
Water Reclamation Facility

Transmission piping and pumping station designed by CDM

Three 24-inch diameter ASR wells have been constructed and permitted for cycle testing



Three monitor wells have been constructed to monitoring performance of ASR wellfield



MW-2 is a dedicated storage zone monitor well (monitors interval from 1,080 to 1,350 feet)

MW-1 monitors the USDW from 670 to 742 feet

Well development

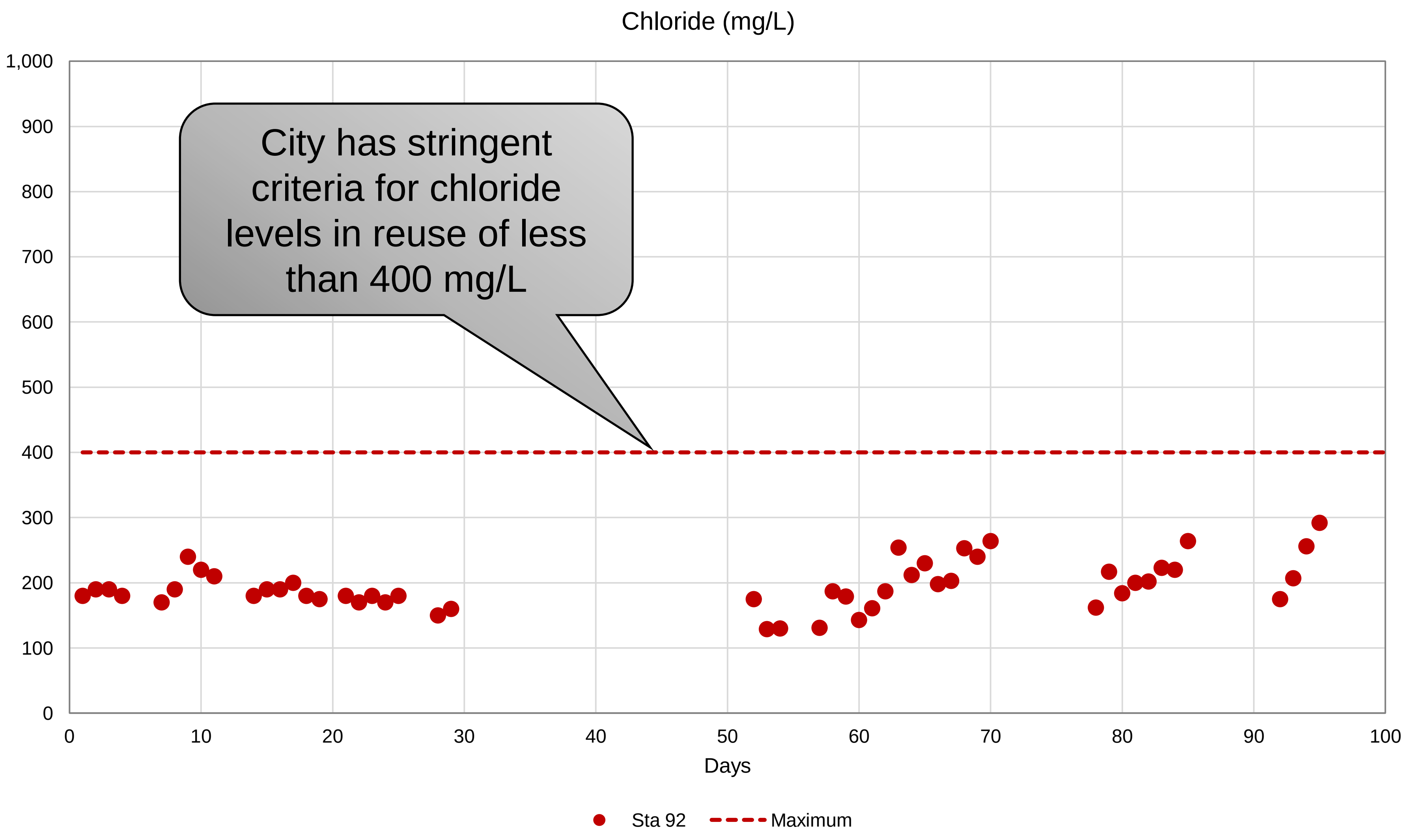
254 ppm

106 ppm

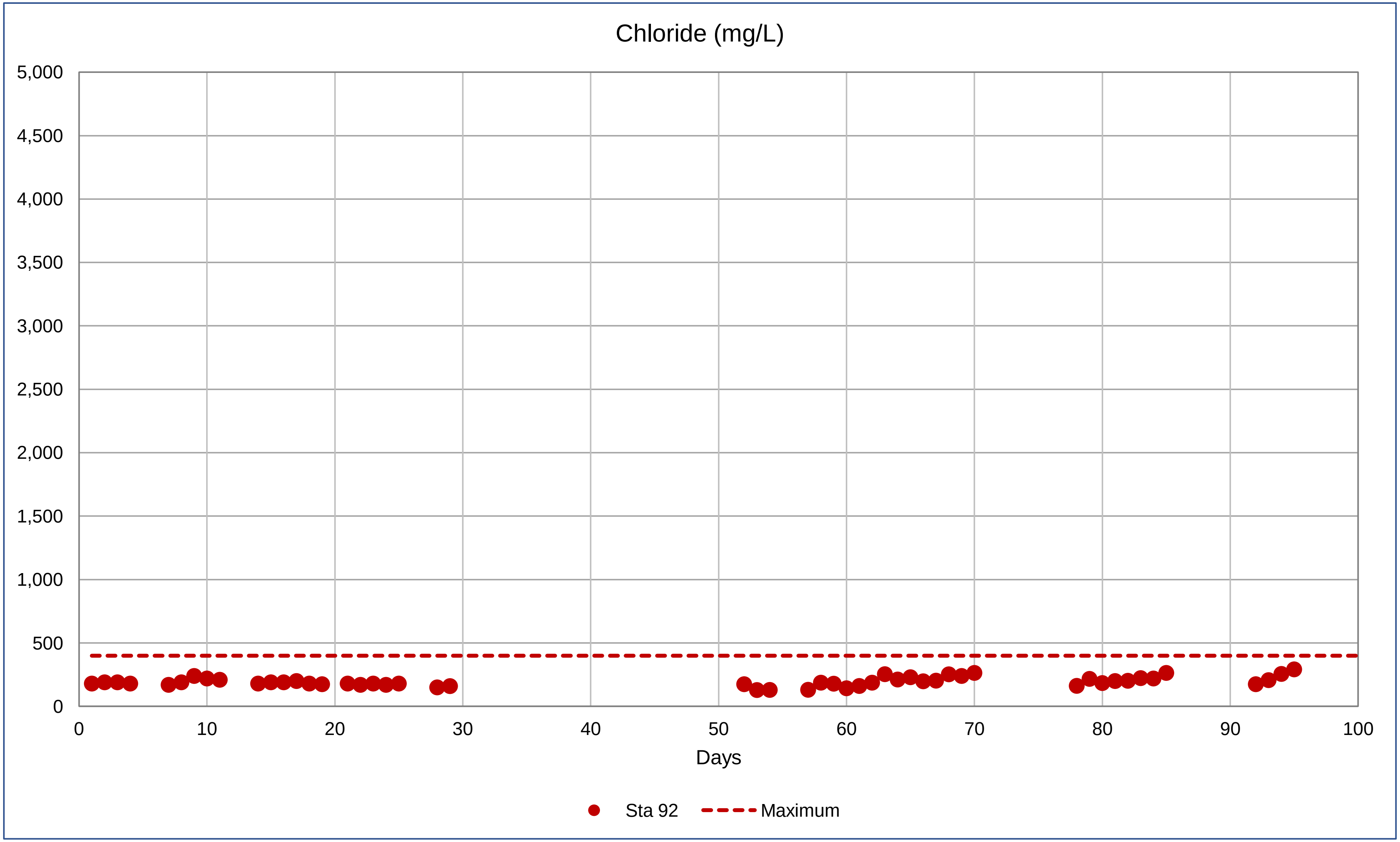
7 ppm

Measuring sand content

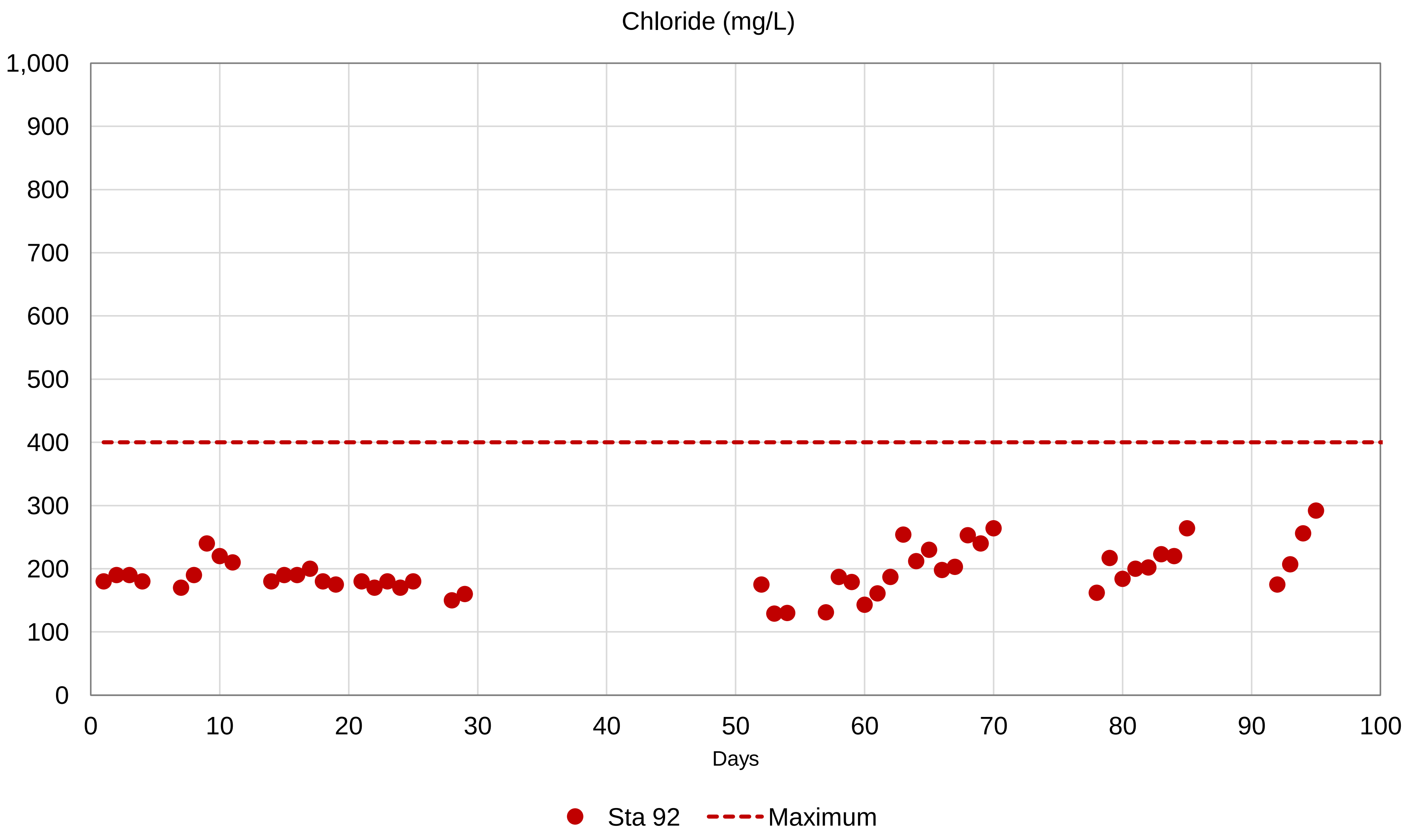
Reuse chloride levels have remained below 400 mg/L during recovery periods



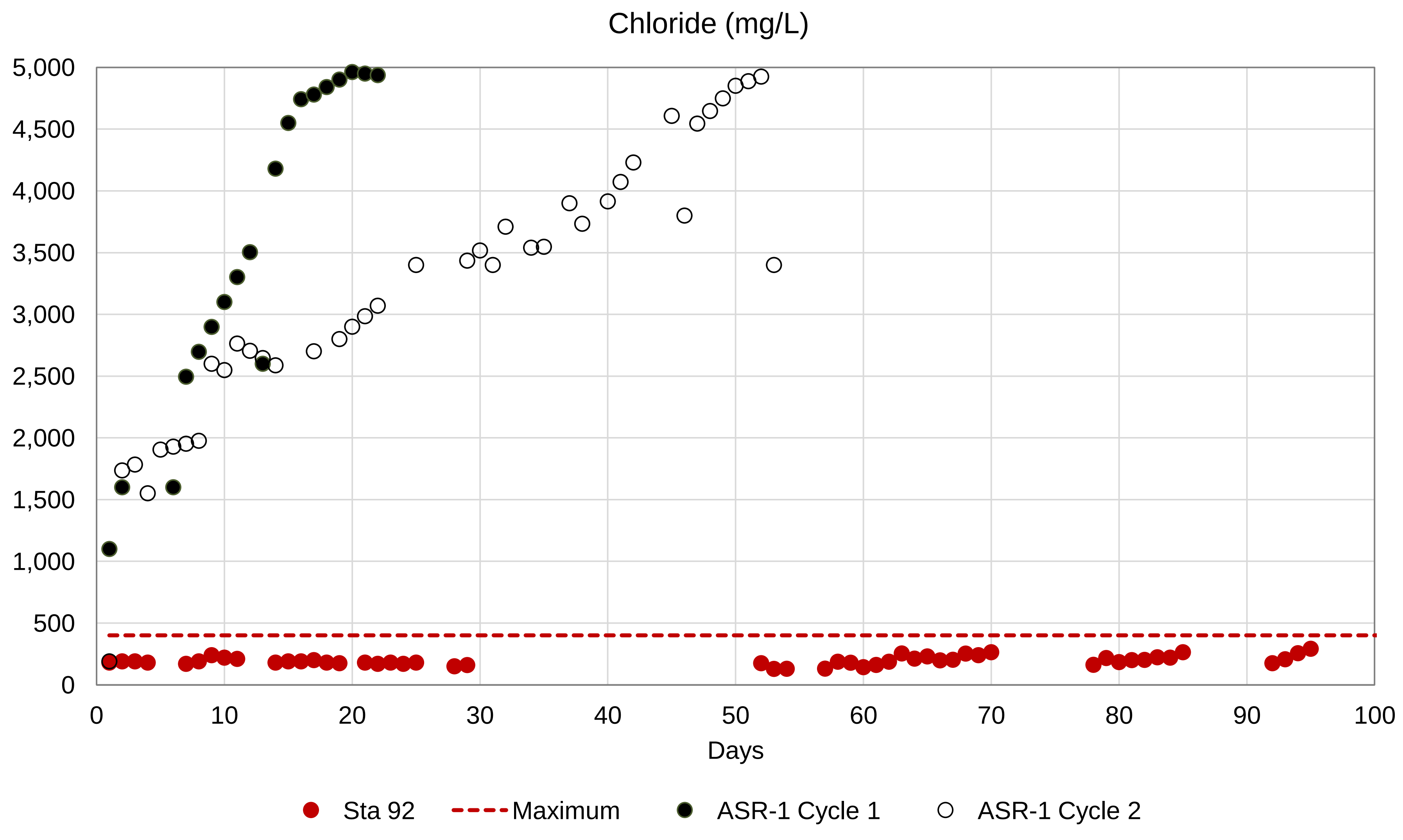
Reuse chloride levels have remained below 400 mg/L during recovery periods



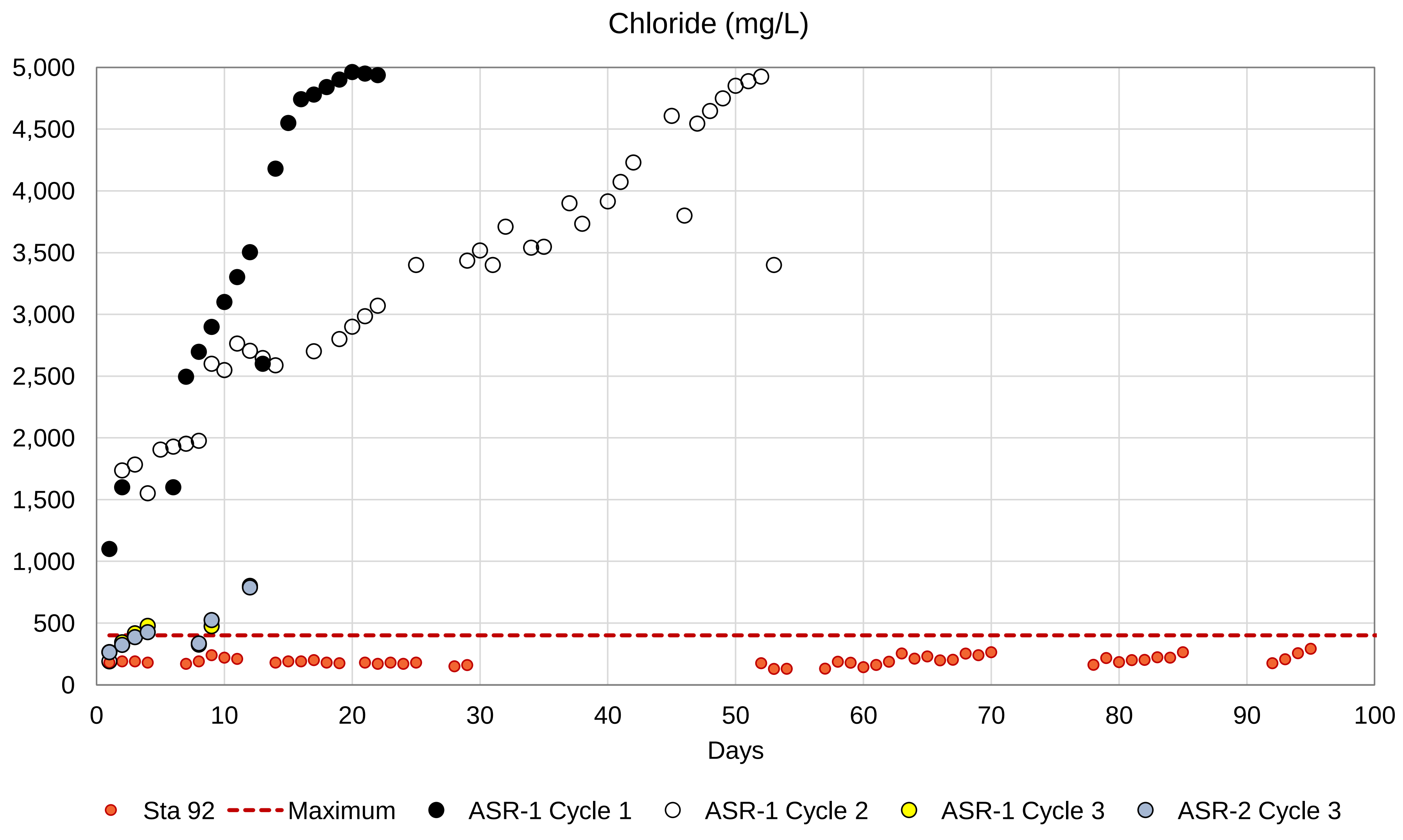
Reuse chloride levels have remained below 400 mg/L during recovery periods



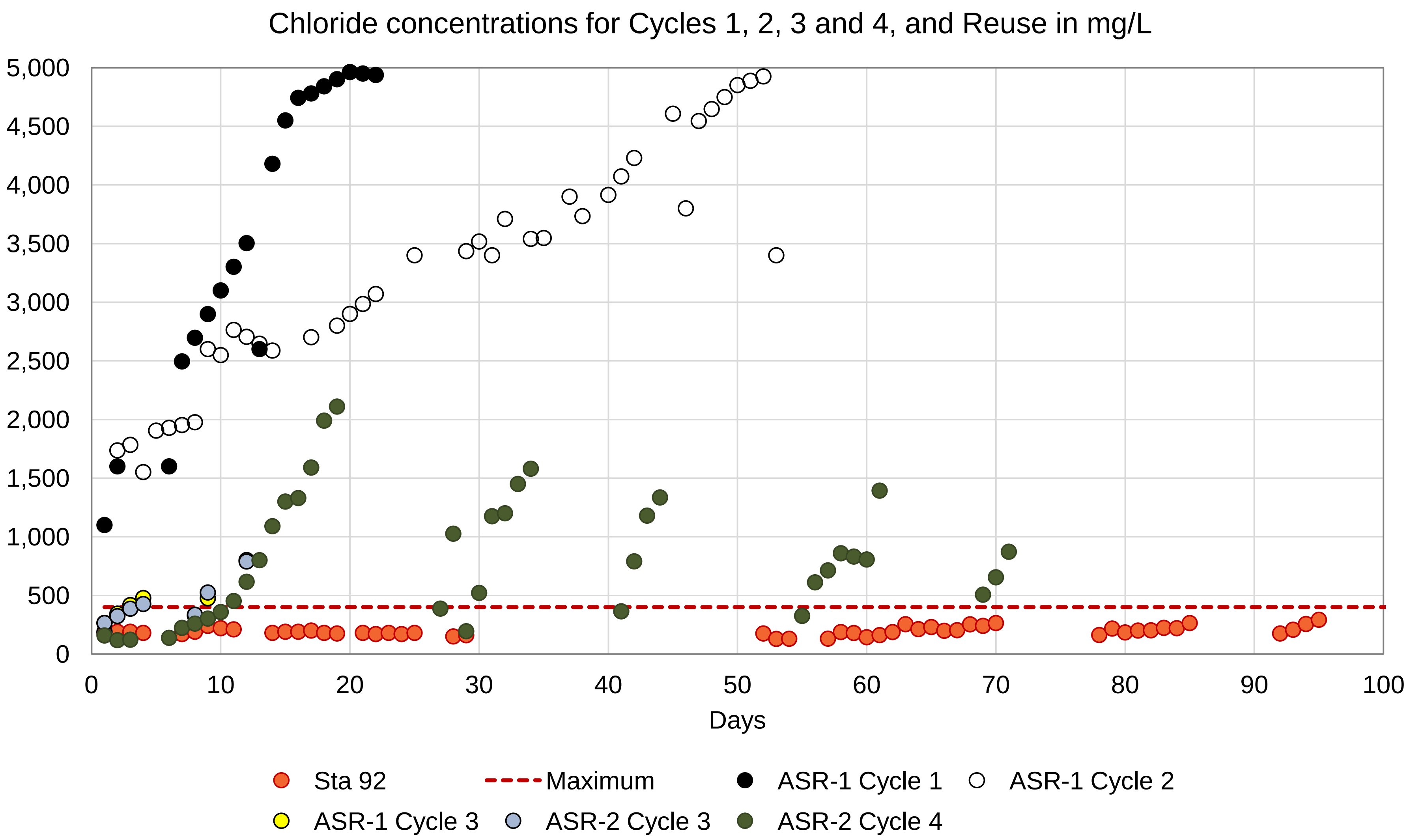
A noticeable improvement was observed with two mini repetitive cycles



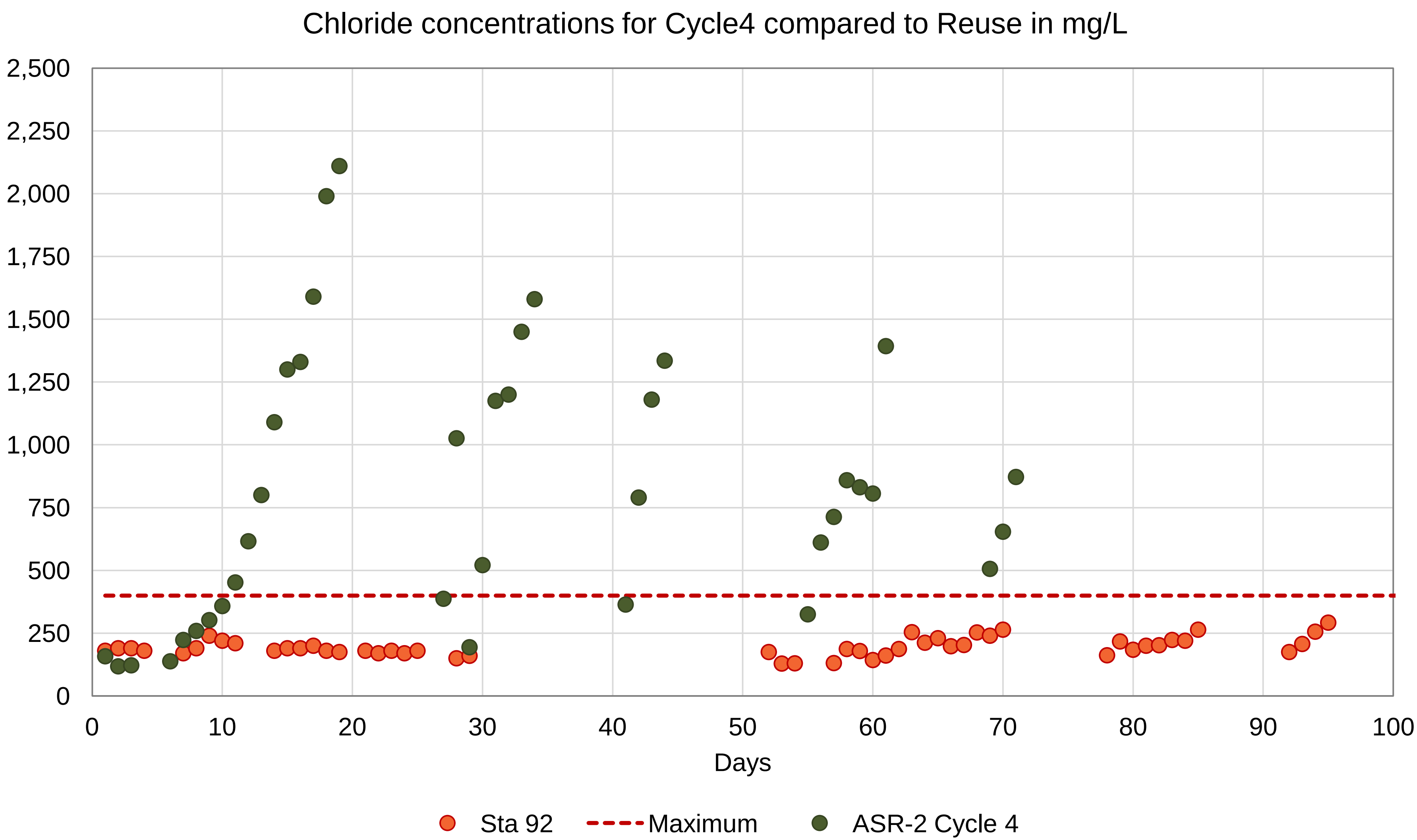
Development of the storage horizon continues to improve with “flushing”



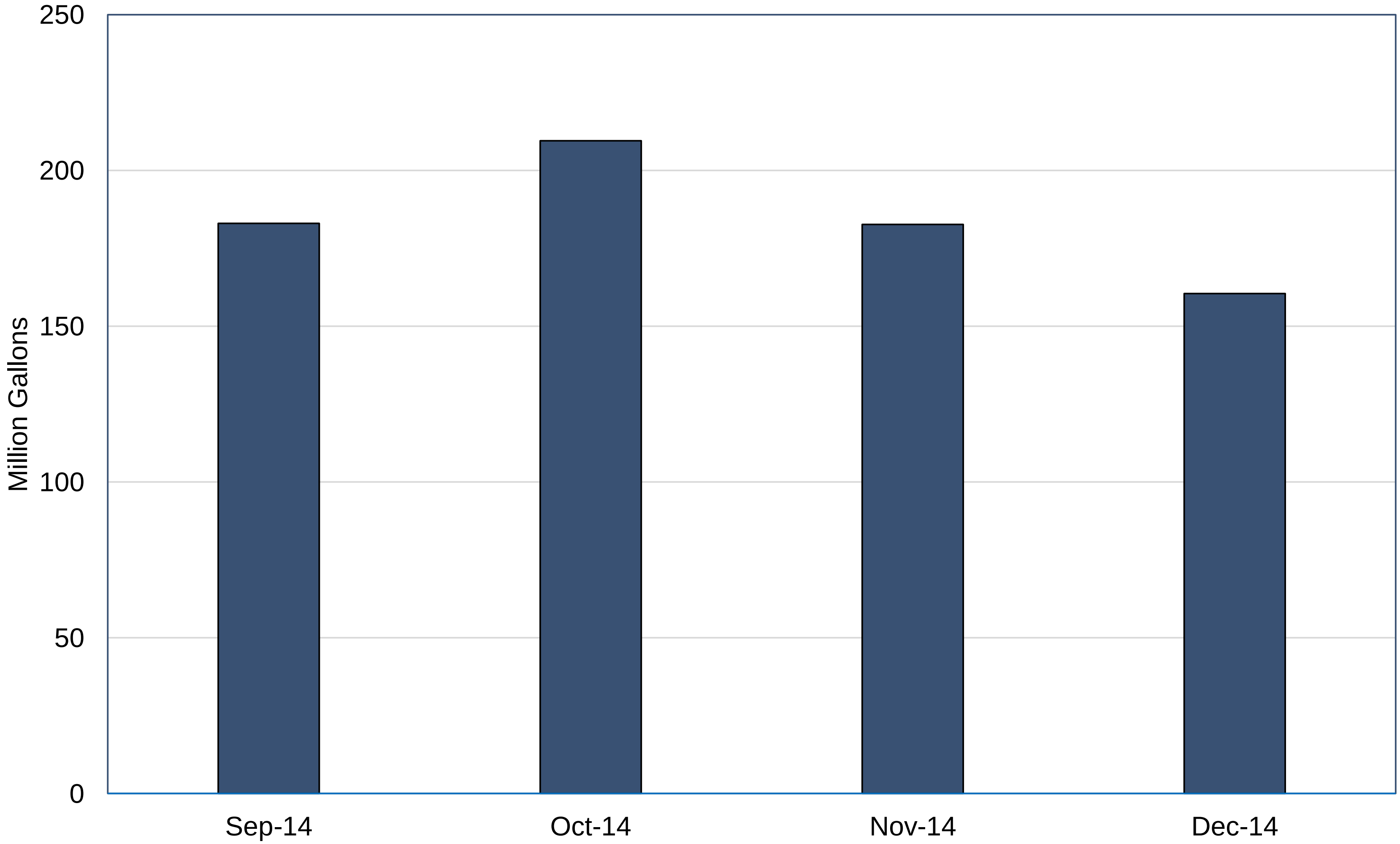
Recent recovery event shows that we can operate for extended periods



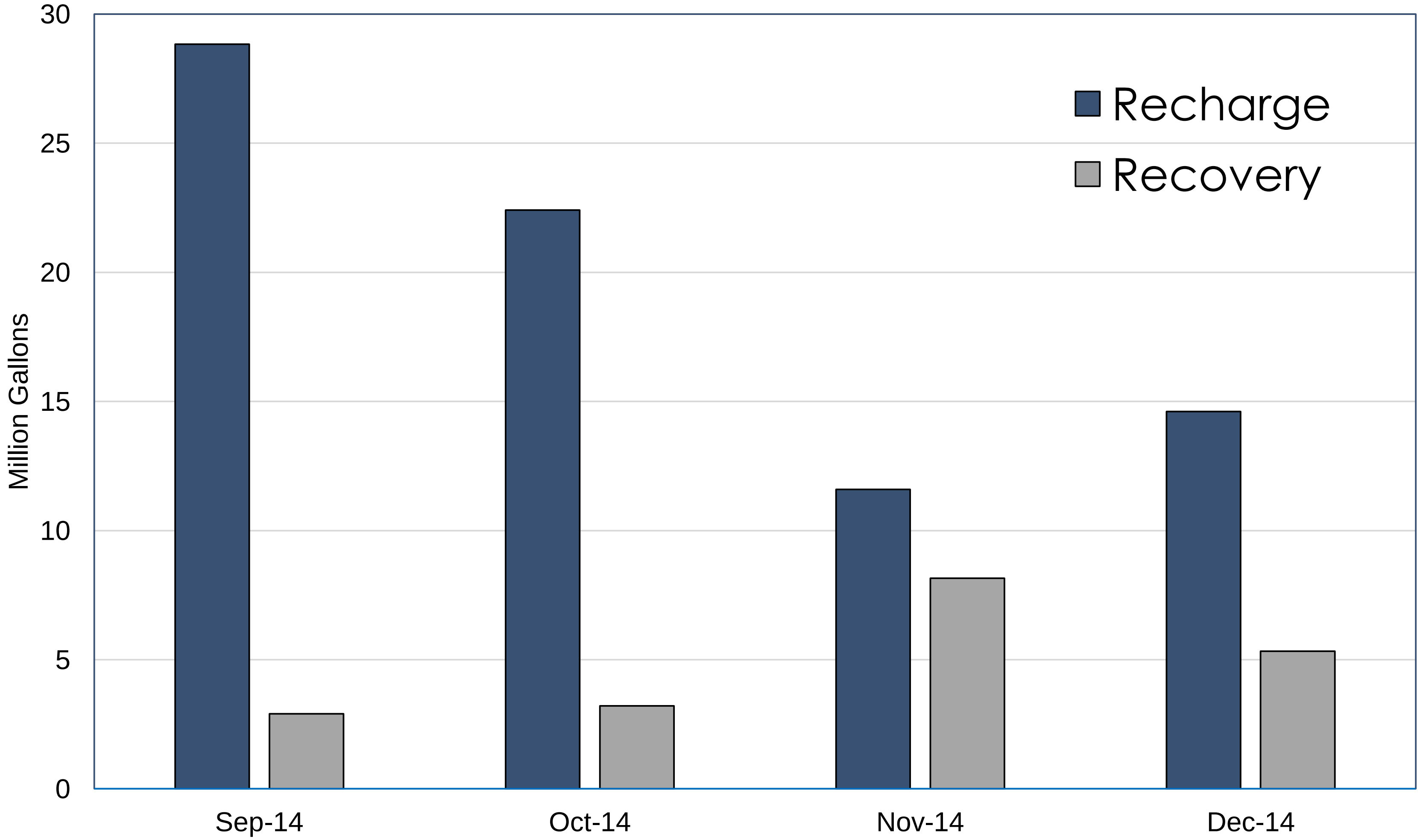
Recent recovery event shows that we can operate for extended periods



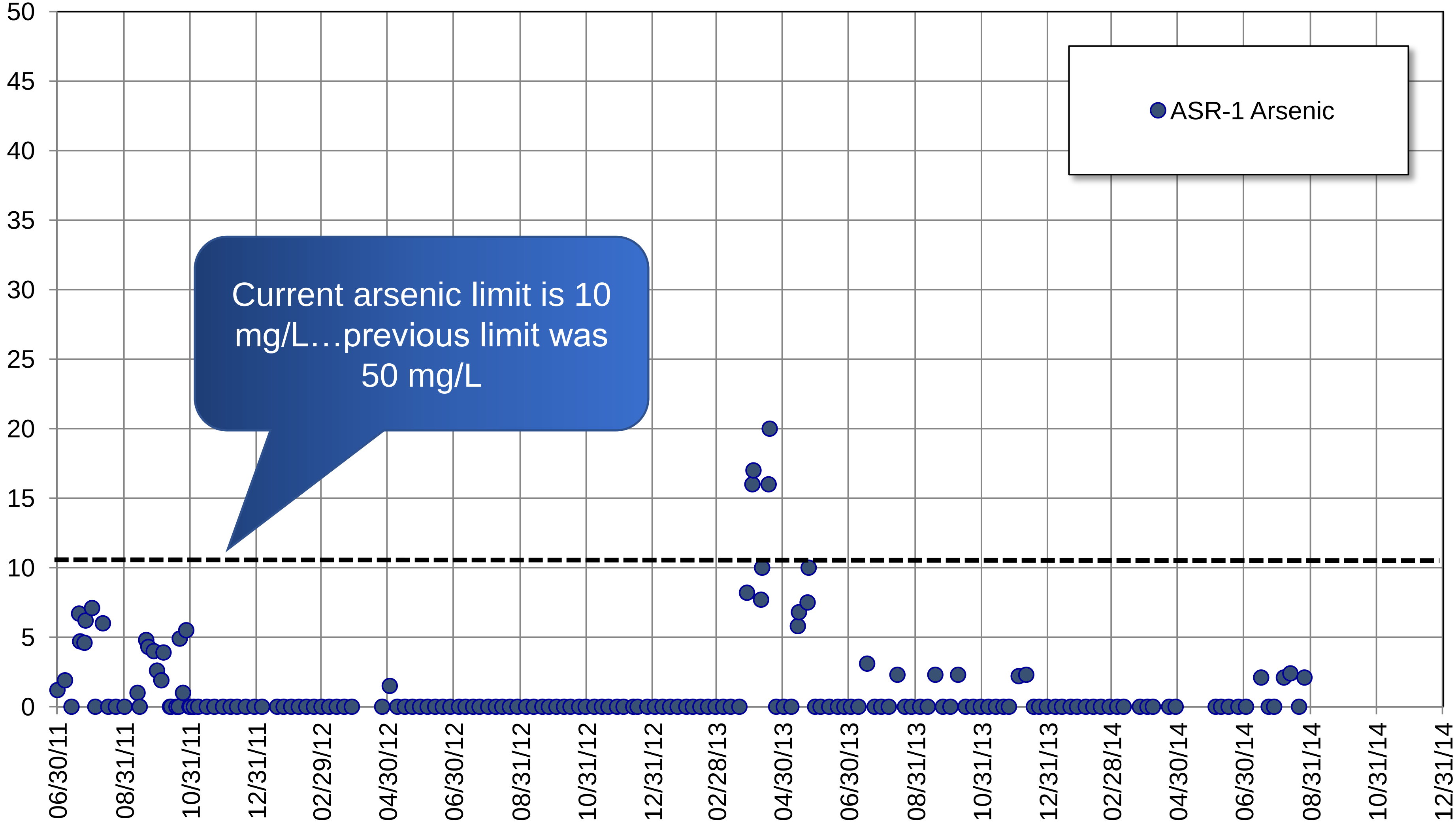
Water reclamation facility monthly influent flow

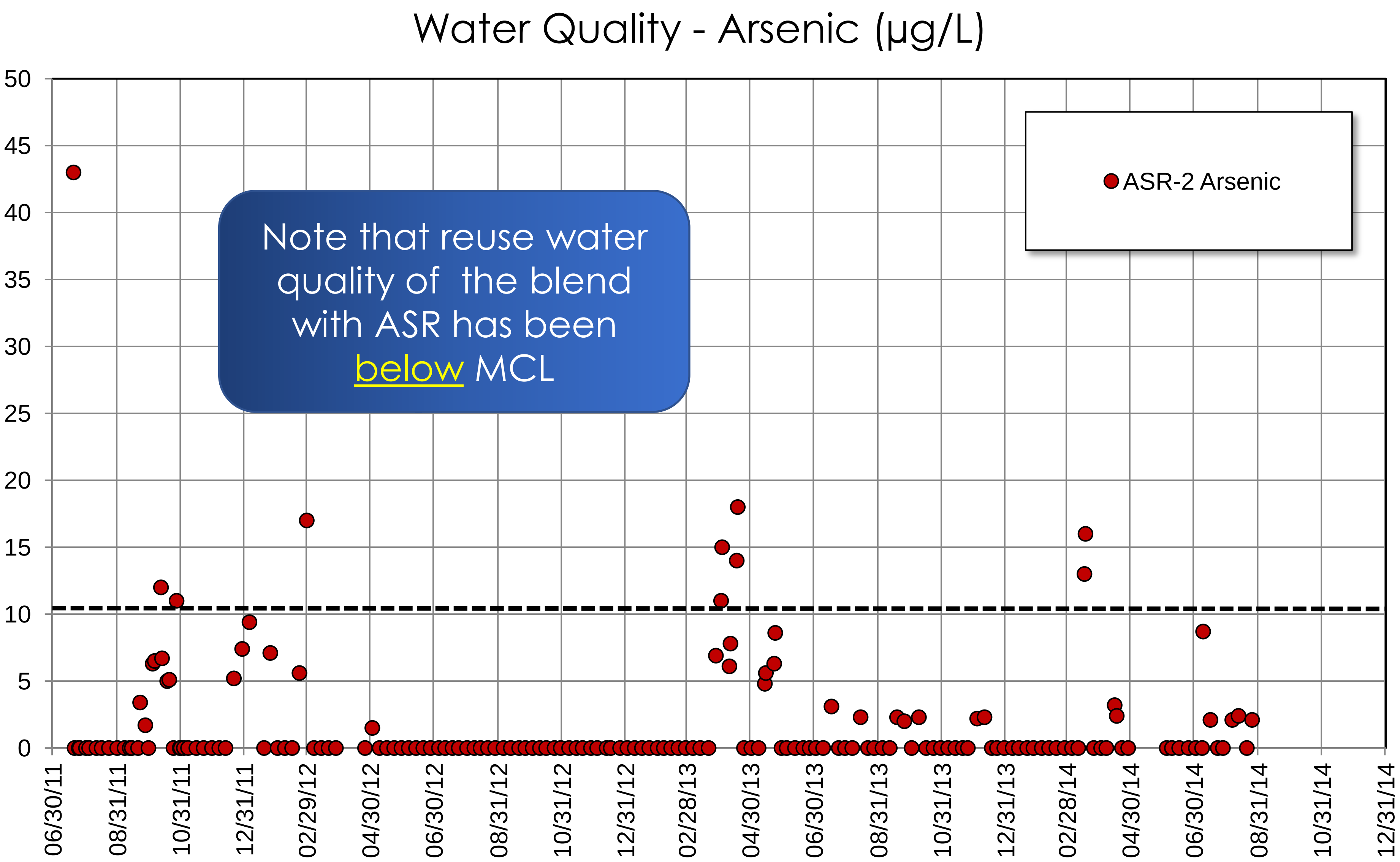


Days recovered from ASR Well No. 2…based on demands



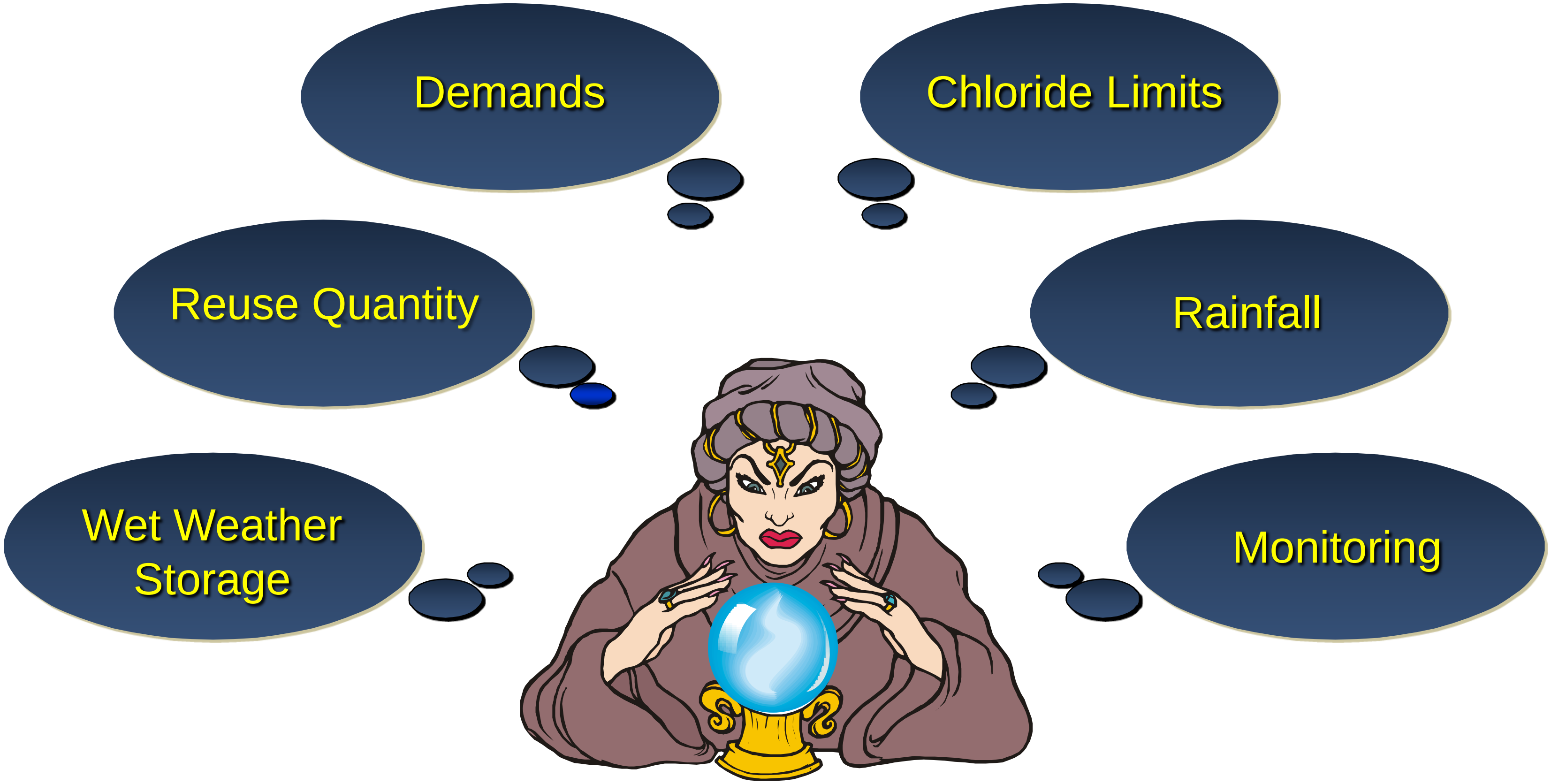
Water Quality - Arsenic (µg/L)





Water Quality - Arsenic (µg/L)
50
45
40
35
30
25
20
15
10
5
0
06/30/11
08/31/11
10/31/11
12/31/11
02/29/12
04/30/12
06/30/12
08/31/12
10/31/12
12/31/12
02/28/13
04/30/13
06/30/13
08/31/13
10/31/13
12/31/13
02/28/14
04/30/14
06/30/14
08/31/14
10/31/14
12/31/14
ASR-2 Arsenic
Note that reuse water quality of the blend with ASR has been below MCL

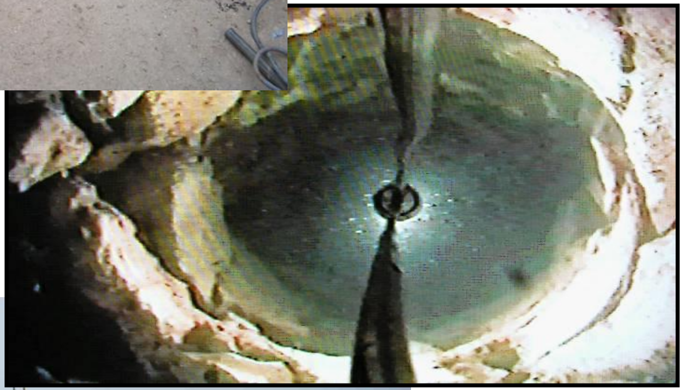
Many factors must be considered for optimal operation of the ASR system



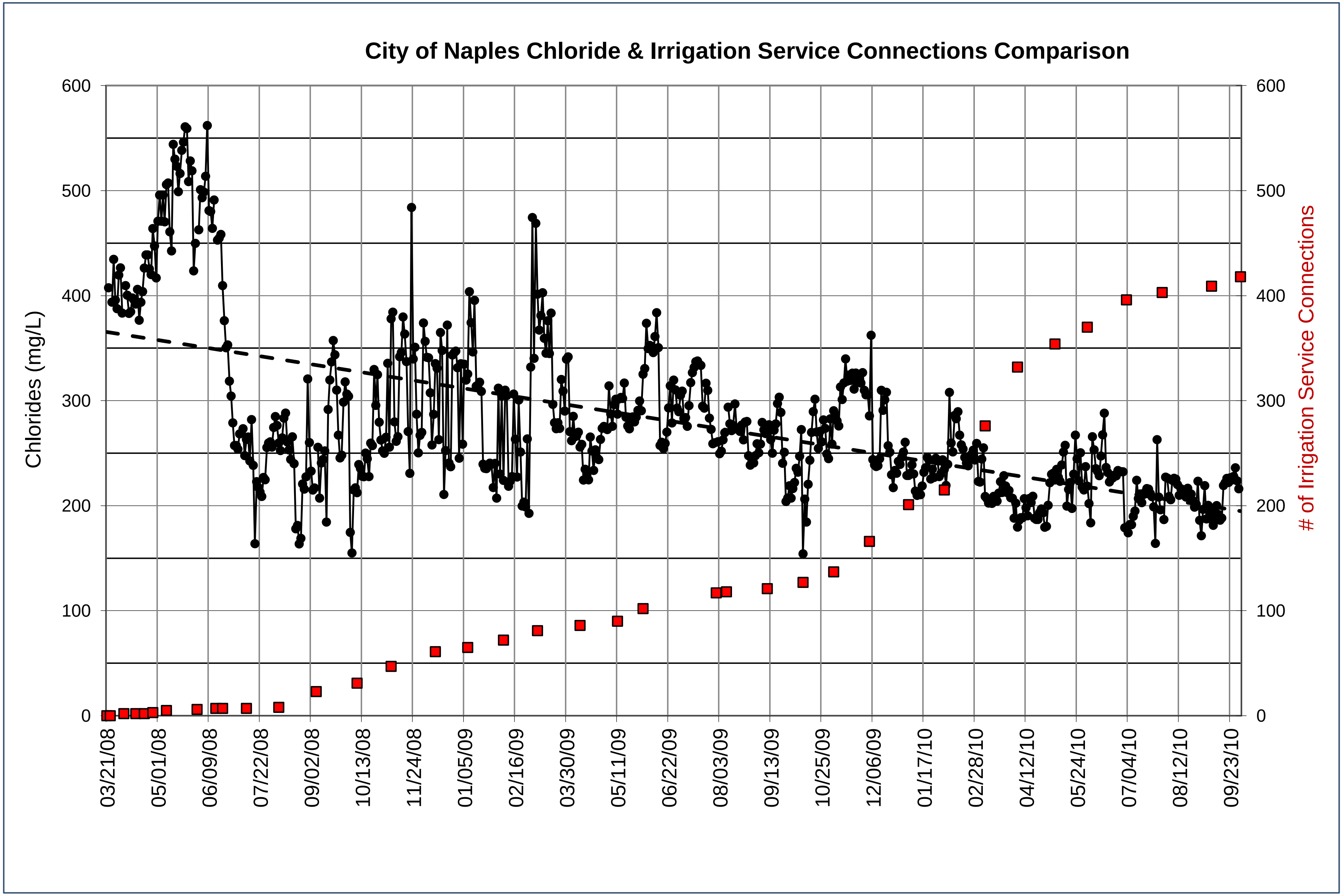
Wet weather assist in reducing in pollutant loads to surface waters

- Total nitrogen ~ 1.7 mg/L
- Total phosphorus ~ 0.32 mg/L
- Million gallons stored ~ 2,100 million gallons
- Reduction of pollutants
  - Nitrogen ~ 29,770 lbs
  - Phosphorus ~ 5,600 lbs
  - Total load reduction ~ 35,375 lbs


08.07.2009



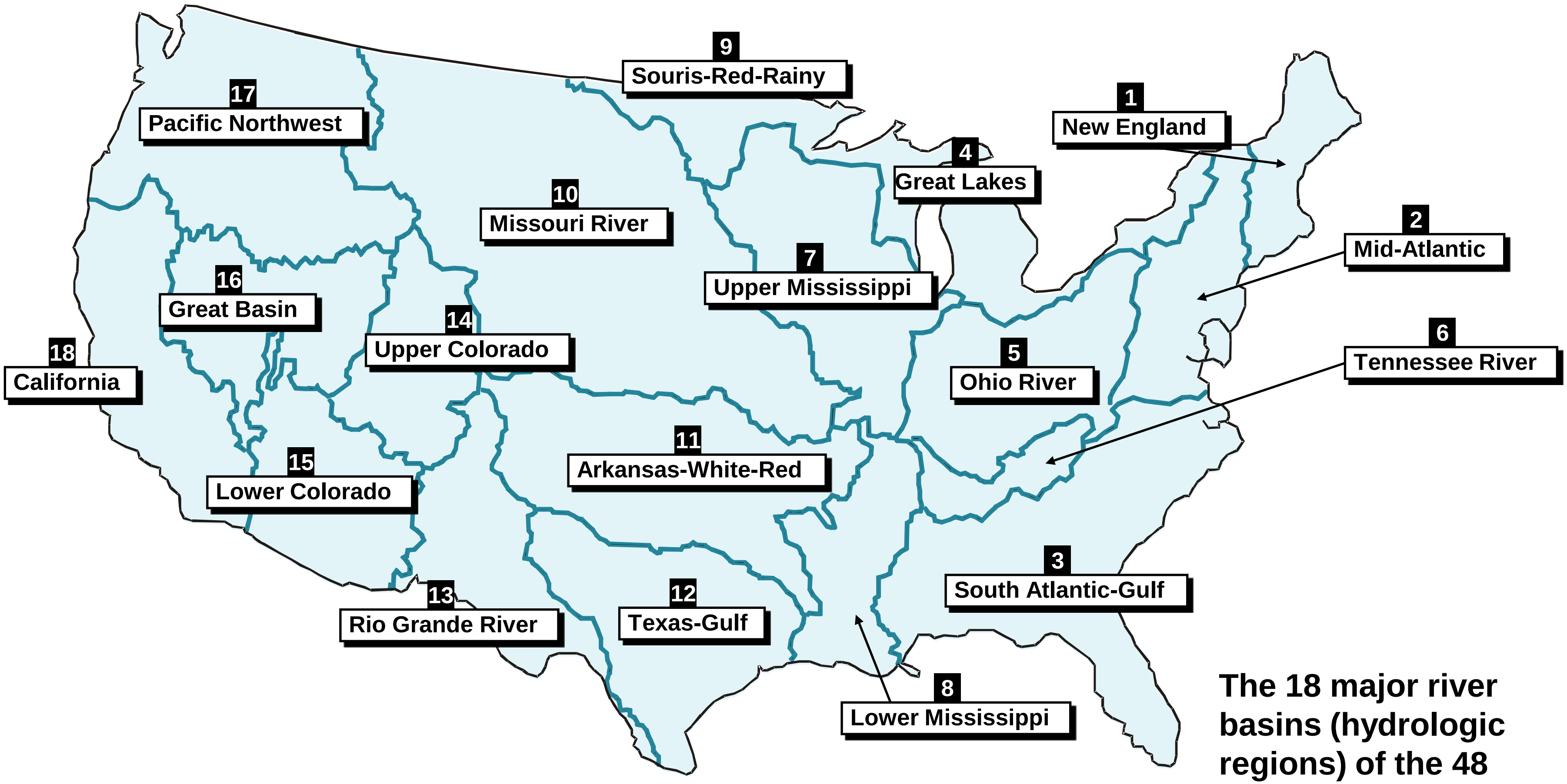

08.07.2009


City of Naples Chloride & Irrigation Service Connections Comparison
Chlorides (mg/L)
# of Irrigation Service Connections
0
100
200
300
400
500
600
03/21/08
05/01/08
06/09/08
07/22/08
09/02/08
10/13/08
11/24/08
01/05/09
02/16/09
03/30/09
05/11/09
06/22/09
08/03/09
09/13/09
10/25/09
12/06/09
01/17/10
02/28/10
04/12/10
05/24/10
07/04/10
08/12/10
09/23/10

Challenges

How to manage resources for demand(s) while complying with regulations

Remember NIMBY



The 18 major river basins (hydrologic regions) of the 48 contiguous states

Little known Mississippi River facts

16,300 MGD discharge

11,500 point sources

Water supply for over 50 Cities

Mississippi River

The Mississippi River

Current treatment technologies can treat impaired waters to achieve very high water quality standards, but at what price?

Can we do a better job?

- Minimize pollution
- Manage better
- Accommodate higher levels of treatment

Conclusions

Conclusions

- Expectations – Managing expectations are critical components of a project
- Design and Performance Criteria – Planning should accommodate flexibility in design and testing to address underground conditions encountered
- Permitting – Regulators need more flexibility to allow testing for advancement of technologies
- Lessons Learned – Reporting of findings needs to be complete and professional to avoid misconceptions and misrepresentation of facts

The Future

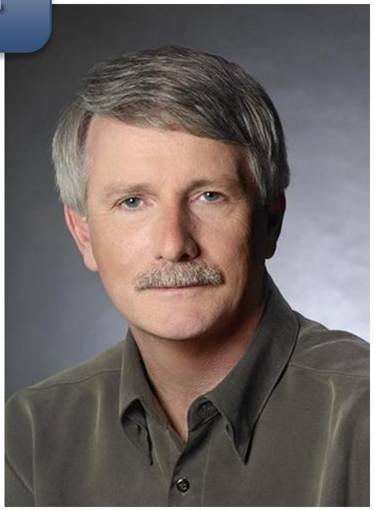
What and where are the future opportunities?

How can science be advanced?

"Sure, its' a great innovation, but does it Comply with all government guidelines?"

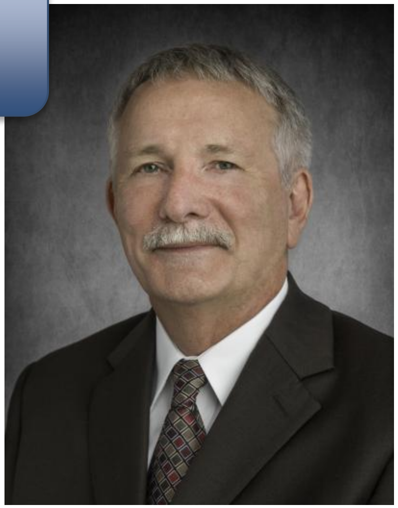
Question?

Then…



Did the regulations in the 1970s include sufficient flexibility to accommodate advancements in water treatment technologies to allow for economical development of underground sources for potable use?

Now…

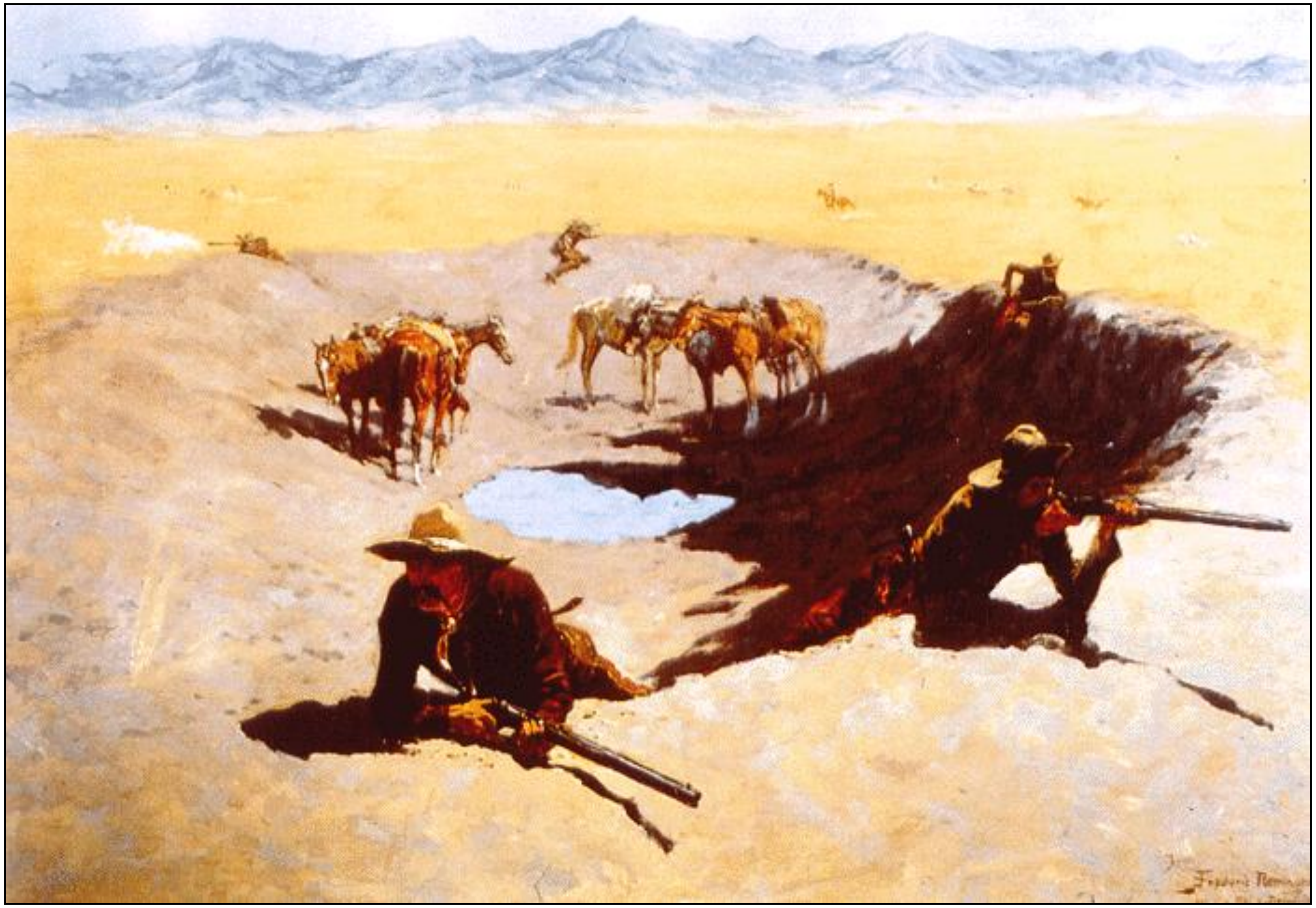


The Future

What and where are the future opportunities?

- Education on applications of the ASR concept is still evolving and should be continued
- Sharing of information within the industry is vital for the industry to learn from prior endeavors
- Continued collaboration with regulators is essential…especially to address monitoring and data gaps
- Allowances for testing of innovative applications (e.g., stacking across aquifers)

Thank you!



Fight for the Waterhole by Frederick Remington

Bullpen

Evaluation of recovery based on water quality

Variable

Description	Scenario 1	Scenario 2	Scenario 3
Reuse chloride	400 mg/L	800 mg/L	1,000 mg/L
Reuse flow	10 mgd	10 mgd	10 mgd
WRF chloride	200 mg/L	200 mg/L	200 mg/L
WRF flow	8 mgd	8 mgd	8 mgd
ASR flow	2 mgd	2 mgd	2 mgd
ASR chloride	1,200 mg/L	3,200 mg/L	4,200 mg/L
ASR conductivity	4,800 µmhos/cm	12,800 µmhos/cm	16,800 µmhos/cm

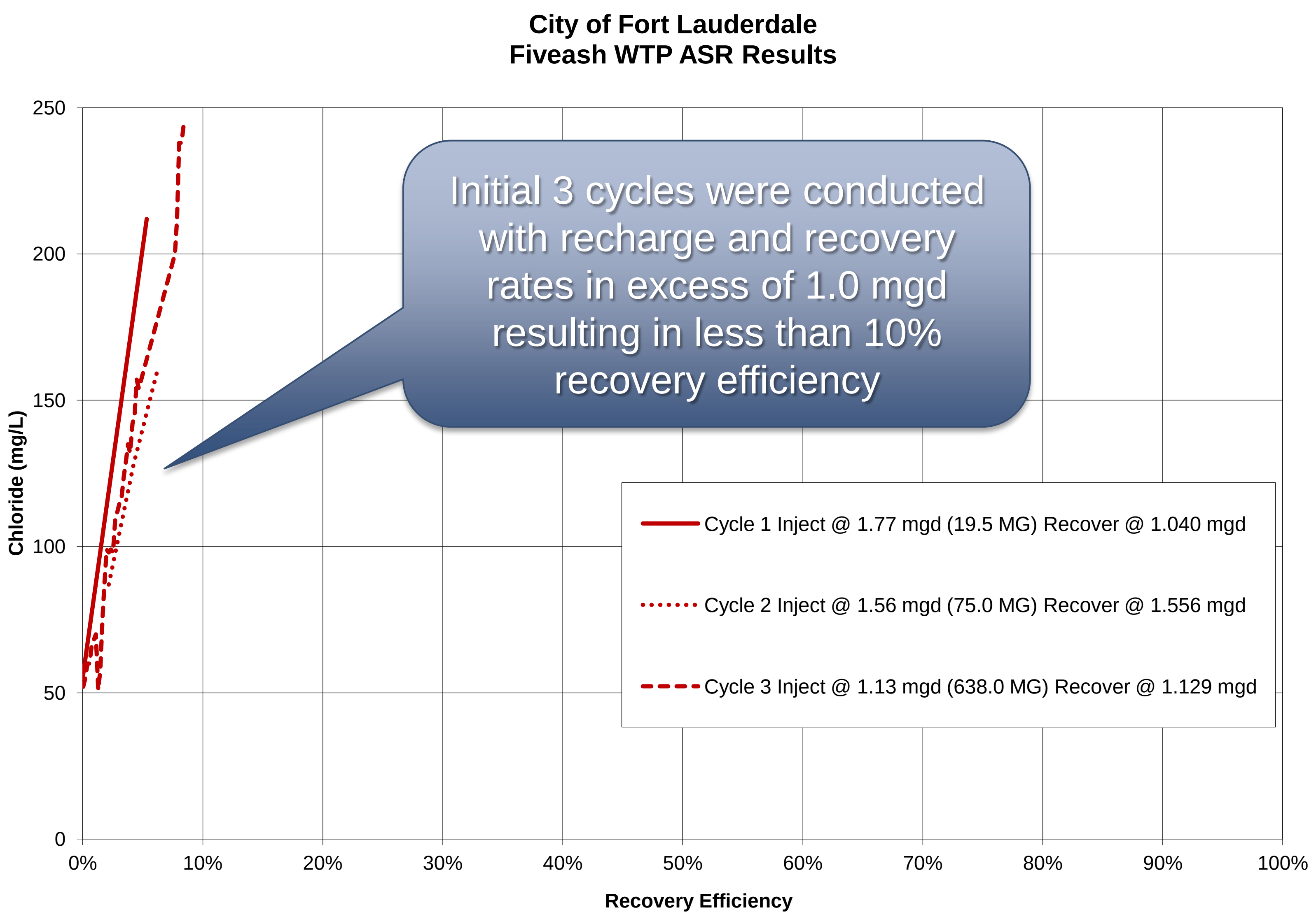
Lessons learned from FKAA Marathon ASR

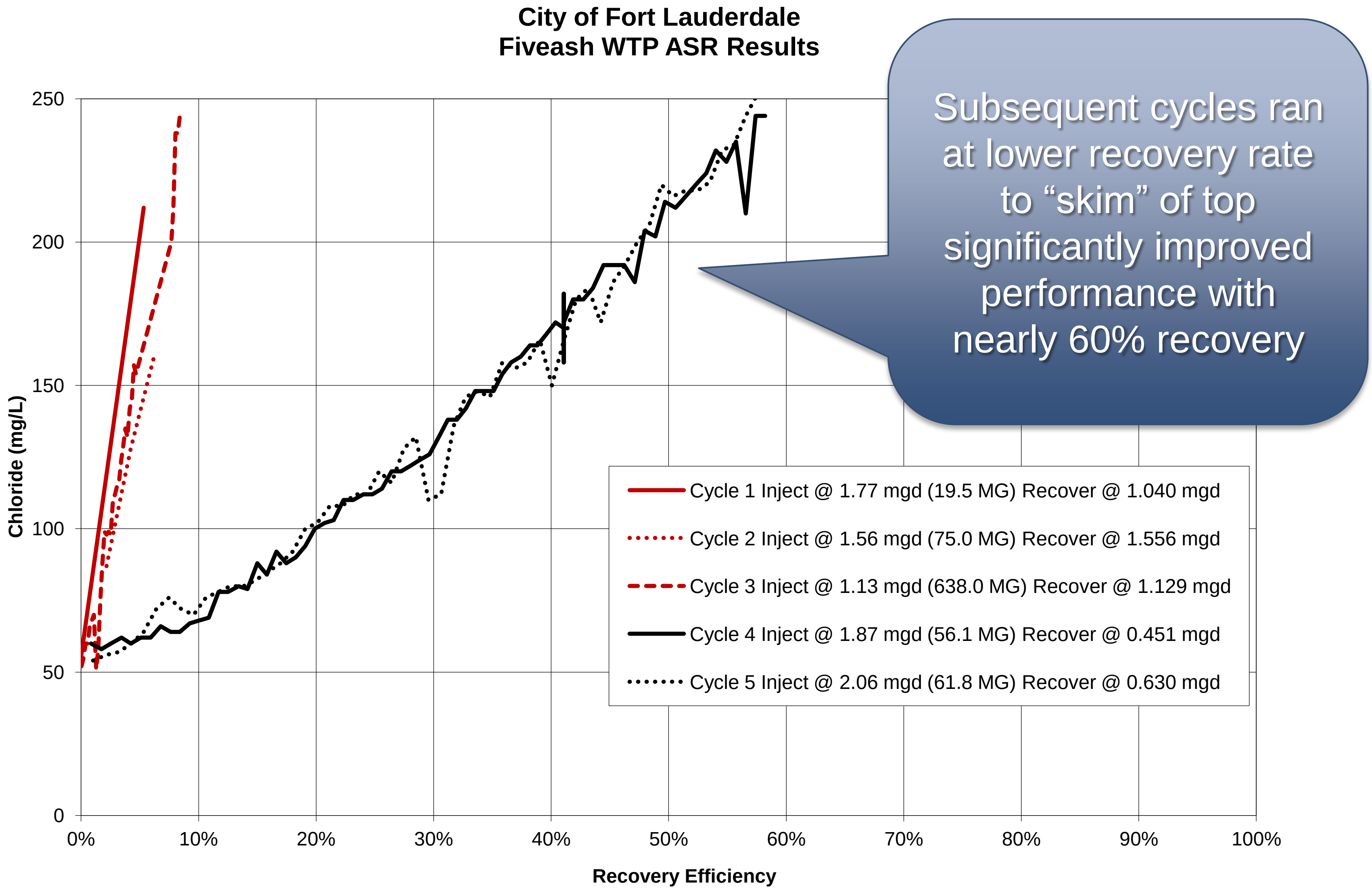
Lessons…

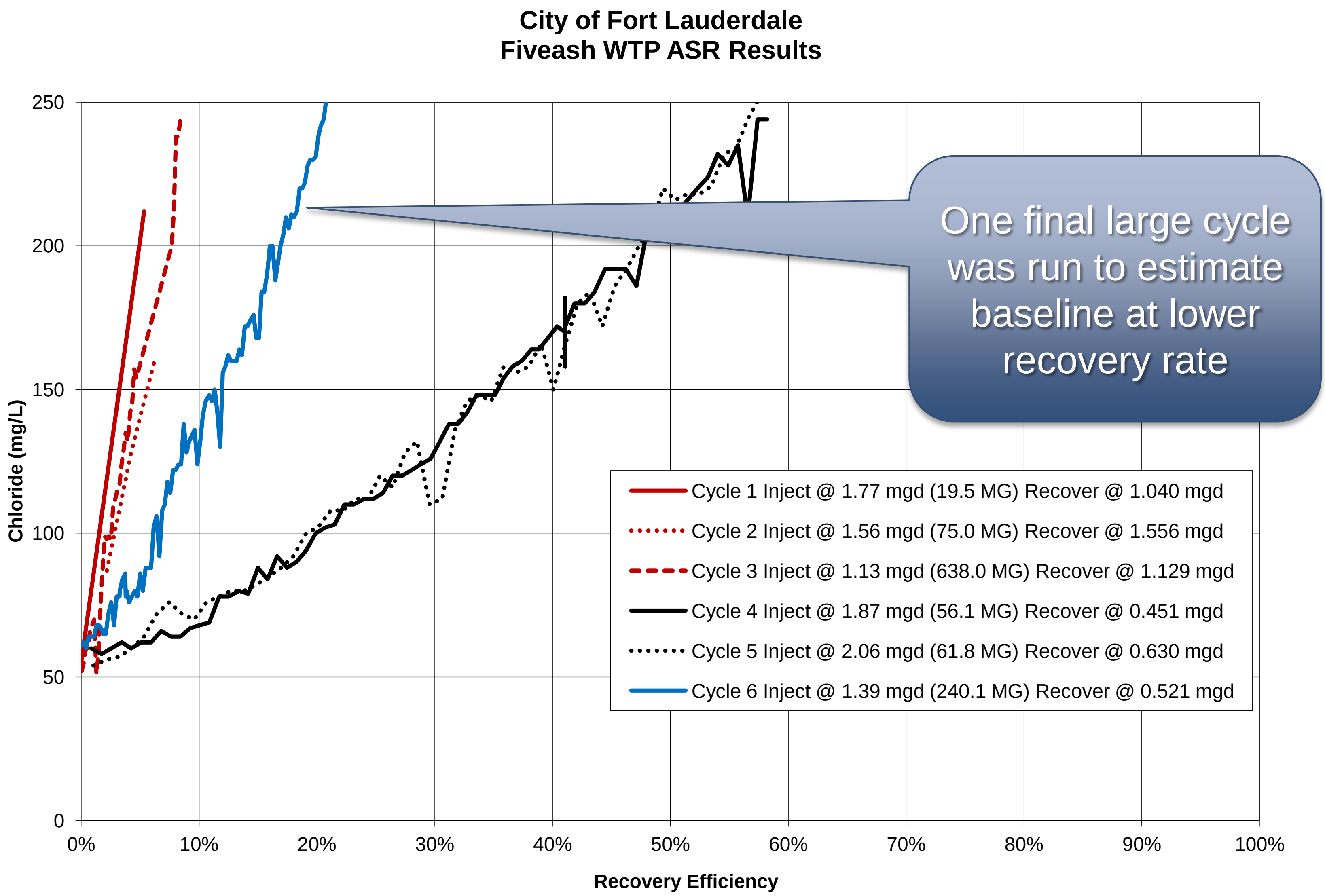
- Selection of storage zone requires tailored testing to confirm performance
- Limited available data…many underground formations have not been properly tested for storage and
- Although more cost effective, client elected to proceed with a more proven option…construction of an RO Water Treatment Plant in Key West
- Understanding project background enables accurate representation of facts

City of Fort Lauderdale Fiveash WTP ASR

Testing at the modified protocol (i.e., reduced recovery rates) improved system performance


City of Fort Lauderdale
Fiveash WTP ASR Results
Initial 3 cycles were conducted with recharge and recovery rates in excess of 1.0 mgd resulting in less than 10% recovery efficiency
Chloride (mg/L)
250
200
150
100
50
0
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
Recovery Efficiency
Cycle 1 Inject @ 1.77 mgd (19.5 MG) Recover @ 1.040 mgd
Cycle 2 Inject @ 1.56 mgd (75.0 MG) Recover @ 1.556 mgd
Cycle 3 Inject @ 1.13 mgd (638.0 MG) Recover @ 1.129 mgd

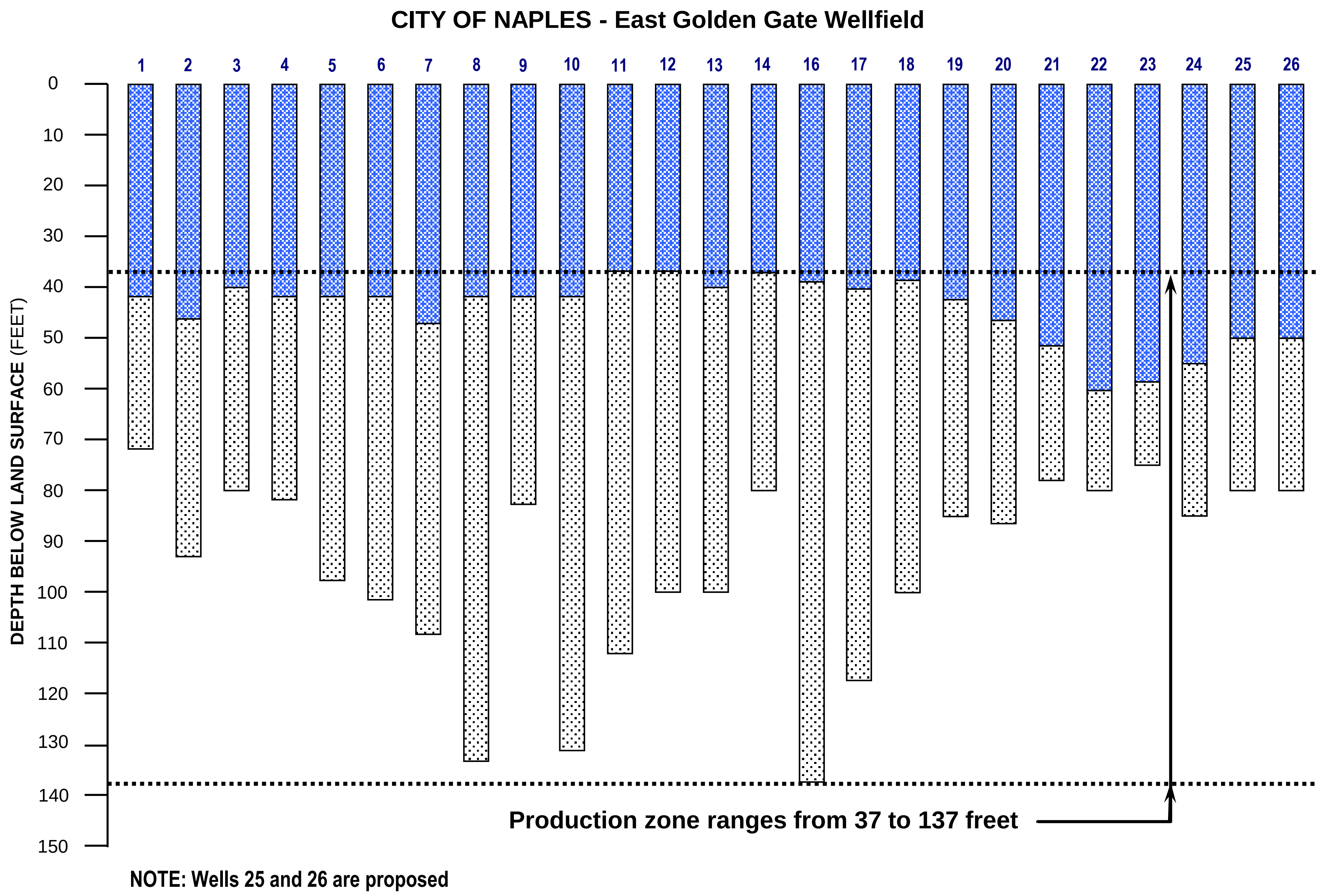

City of Fort Lauderdale
Fiveash WTP ASR Results
Chloride (mg/L)
250
200
150
100
50
0
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
Recovery Efficiency
Cycle 1 Inject @ 1.77 mgd (19.5 MG) Recover @ 1.040 mgd
Cycle 2 Inject @ 1.56 mgd (75.0 MG) Recover @ 1.556 mgd
Cycle 3 Inject @ 1.13 mgd (638.0 MG) Recover @ 1.129 mgd
Cycle 4 Inject @ 1.87 mgd (56.1 MG) Recover @ 0.451 mgd
Cycle 5 Inject @ 2.06 mgd (61.8 MG) Recover @ 0.630 mgd
Subsequent cycles ran at lower recovery rate to “skim” of top significantly improved performance with nearly 60% recovery


City of Fort Lauderdale
Fiveash WTP ASR Results
Chloride (mg/L)
0
50
100
150
200
250
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
Recovery Efficiency
One final large cycle was run to estimate baseline at lower recovery rate
Cycle 1 Inject @ 1.77 mgd (19.5 MG) Recover @ 1.040 mgd
Cycle 2 Inject @ 1.56 mgd (75.0 MG) Recover @ 1.556 mgd
Cycle 3 Inject @ 1.13 mgd (638.0 MG) Recover @ 1.129 mgd
Cycle 4 Inject @ 1.87 mgd (56.1 MG) Recover @ 0.451 mgd
Cycle 5 Inject @ 2.06 mgd (61.8 MG) Recover @ 0.630 mgd
Cycle 6 Inject @ 1.39 mgd (240.1 MG) Recover @ 0.521 mgd

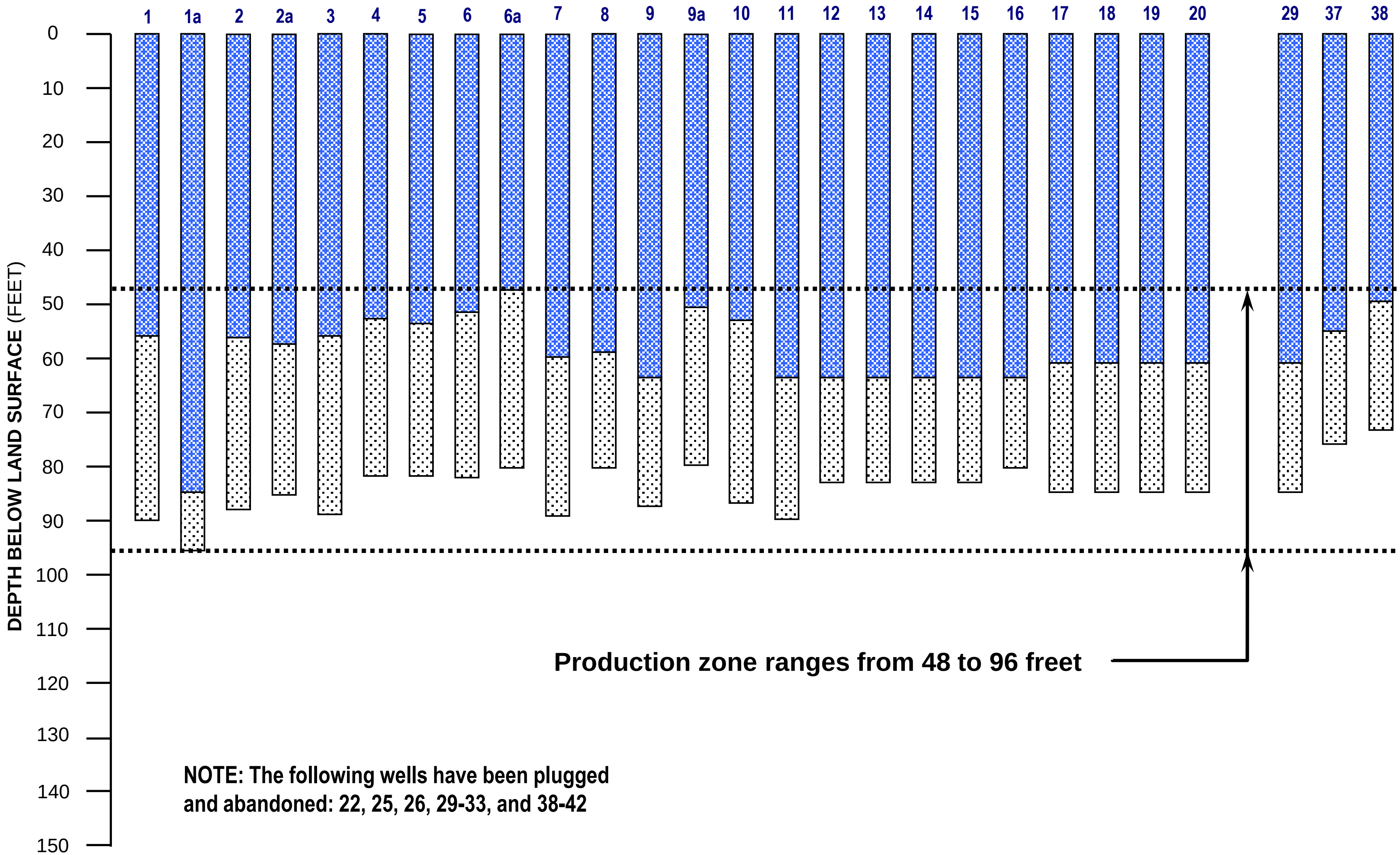
Lessons learned from Broward 2A ASR

Lessons…

- Selection of a storage zone containing brackish water requires close attention to well construction and testing
- Testing must be tailored to both hydraulics and storage zone water quality to maximize recovery
- Understanding that success when storing potable water in brackish / saltwater environments may not achieve 100% recovery


CITY OF NAPLES - East Golden Gate Wellfield
1 2 3 4 5 6 7 8 9 10 11 12 13 14 16 17 18 19 20 21 22 23 24 25 26
0 10 20 30 40 50 60 70 80 90 100 110 120 130 140 150
DEPTH BELOW LAND SURFACE (FEET)
Production zone ranges from 37 to 137 freet
NOTE: Wells 25 and 26 are proposed

CITY OF NAPLES - Coastal Ridge Wellfield



NOTE: The following wells have been plugged and abandoned: 22, 25, 26, 29-33, and 38-42

Background of overall program

1. Develop 5 MGD of alternative water sources
2. Reduce consumption of potable water from 270 gallons per capita per day (GPCD) to below 200 GPCD
3. Conserve existing potable water supply from the Lower Tamiami Aquifer
4. Increase supply of supplemental water for irrigation
5. Reduce reliance on expanded water treatment facilities
6. Meet conditions of renewed water use permit, 100% reclaimed status
7. Achieve the above at least cost to water customers

City of Naples supplemental water strategy

- Expand supplemental water supply from the Golden Gate Canal (permitted to a maximum of 10 MGD)
- Transfer Golden Gate Canal water to Riverside Circle for storage and/or distribution to irrigation system
- Discharge reclaimed water to ASR wellfield and eliminate discharge to Gordon River
- Recover blended effluent water and Golden Gate Canal water from wellfield during dry season

Project scope

- Secure water use permits
  - Groundwater – City of Naples Wellfields
    - Coastal Ridge Wellfield
    - East Golden Gate Wellfield
  - Surface Water – Golden Gate Canal
- Design, permit, construct and test ASR wells
- Design, permit and construct ASR surface facilities
- Design, permit and construct conveyance system to transport Golden Gate Canal (i.e., surface water) to the water reclamation facility

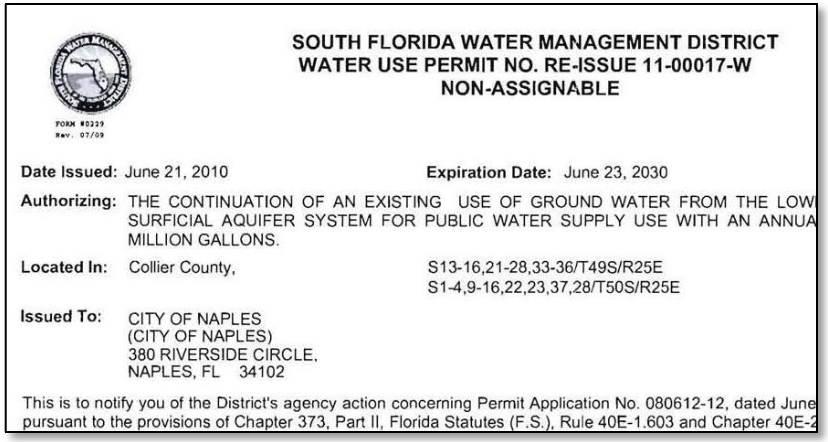
South Florida Water Management District Water Use Permit status update

Groundwater

- Issued Jun 21, 2010
- Expiration Jun 23, 2030
- Duration = 20 years
- Allocations by wellfield
  - Costal Ridge 180.77 MG/Month (5.94 mgd)
  - East Golden Gate Wellfield 505 MG/Month (16.60 mgd)
- Source: Tamiami Aquifer

Surface Water

- Issued = May 9, 2011
- Duration = 20 years
- Requested allocation = 10 mgd
- Source: Excess surface water



SOUTH FLORIDA WATER MANAGEMENT DISTRICT
WATER USE PERMIT NO. RE-ISSUE 11-00017-W
NON-ASSIGNABLE

FORM #0329
Rev. 07/09

Date Issued: June 21, 2010 **Expiration Date:** June 23, 2030

Authorizing: THE CONTINUATION OF AN EXISTING USE OF GROUND WATER FROM THE LOW SURFICIAL AQUIFER SYSTEM FOR PUBLIC WATER SUPPLY USE WITH AN ANNUA MILLION GALLONS.

Located In: Collier County, S13-16,21-28,33-36/T49S/R25E S1-4,9-16,22,23,37,28/T50S/R25E

Issued To: CITY OF NAPLES
(CITY OF NAPLES)
380 RIVERSIDE CIRCLE,
NAPLES, FL 34102

This is to notify you of the District's agency action concerning Permit Application No. 080612-12, dated June pursuant to the provisions of Chapter 373, Part II, Florida Statutes (F.S.), Rule 40E-1.603 and Chapter 40E-2

Pros and Cons of ASR

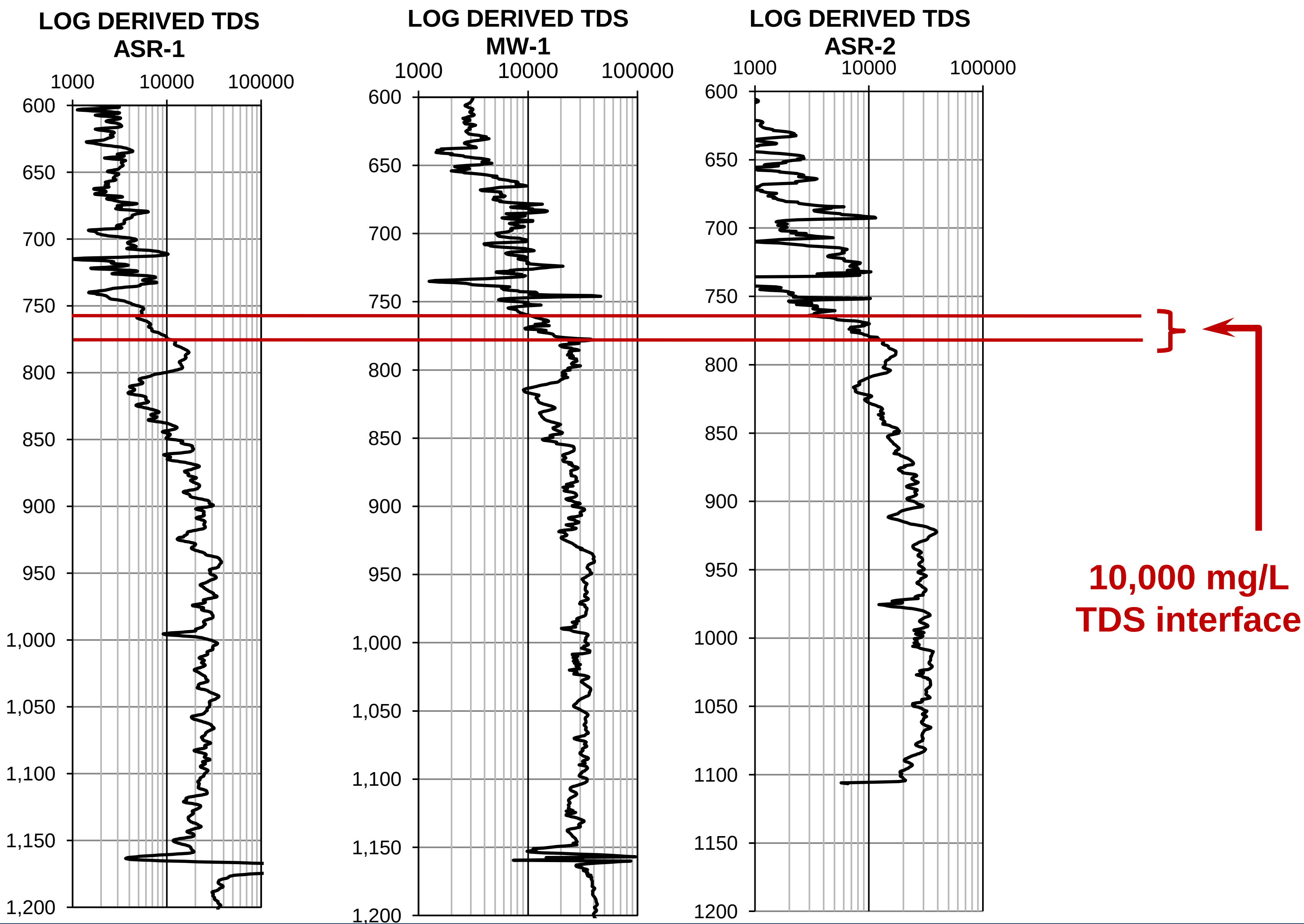
Pros

- Minimal land requirements
- Capacity
- Shelf life
- Peak shaving
- Natural treatment
- Reliability
- Seasonal storage (short and long term)

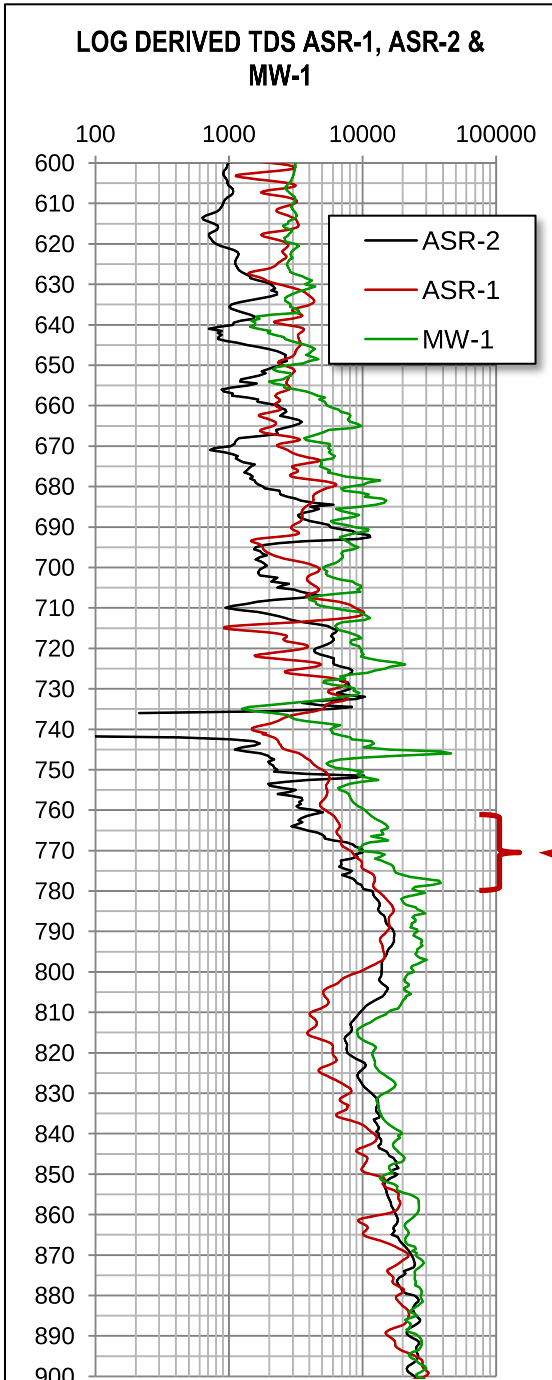
Cons

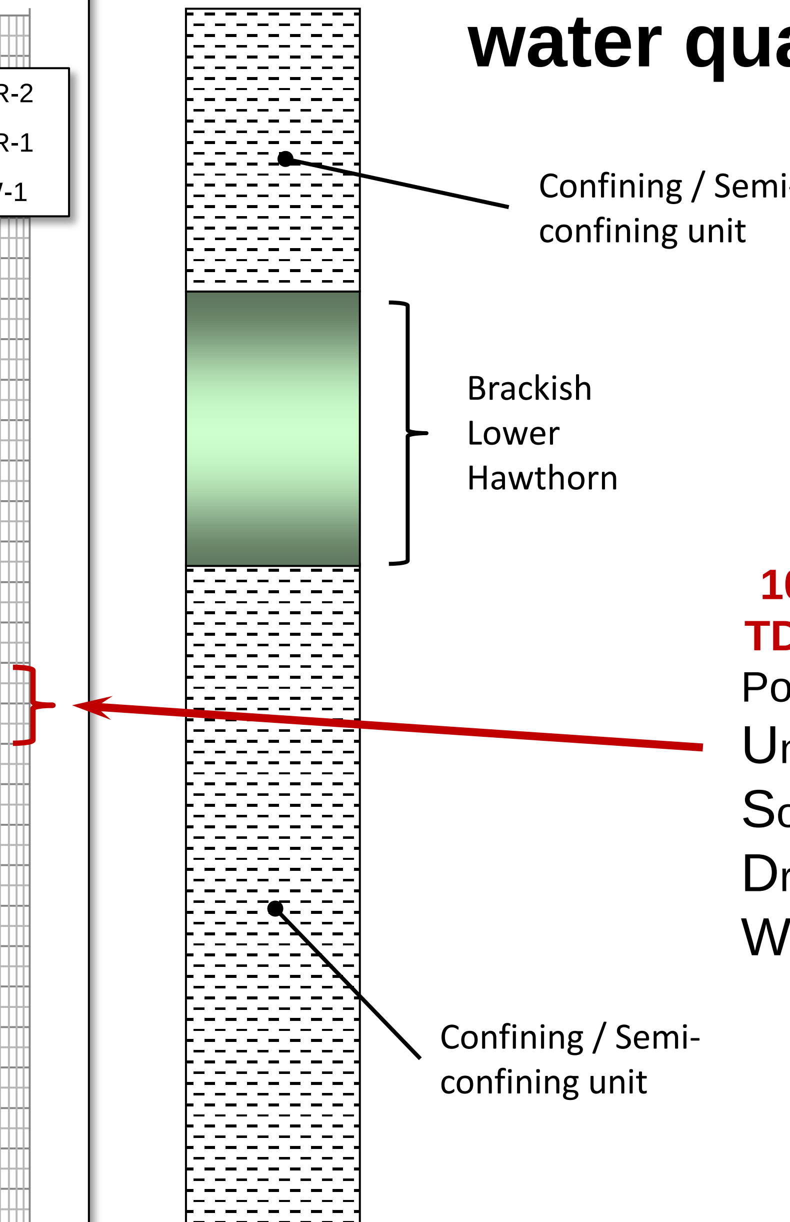
- Unknown
- Hydrogeology
- Regulations
- Adjacent users

Log derived geophysical logging tools used to estimate the location of the USDW



Log derived water quality – TDS

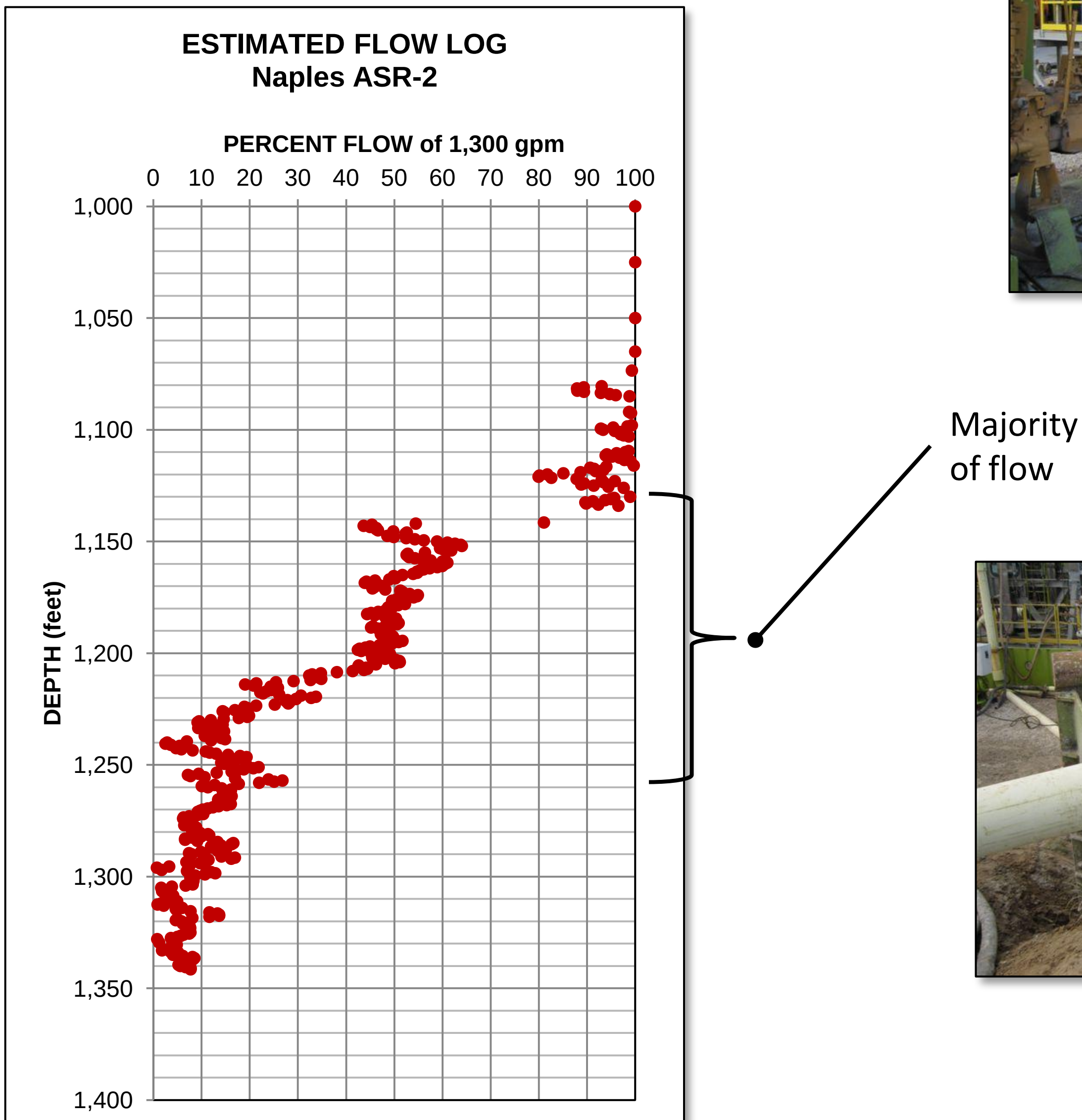


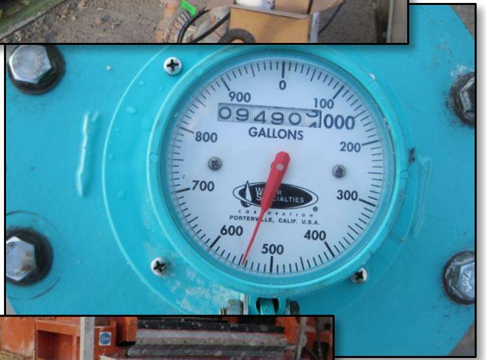


10,000 mg/L TDS interface

Potential Underground Source of Drinking Water

Pumping test used to select the potential storage horizon(s)





Packer testing also used to collect water quality data

Straddle packer testing was performed at ASR-1 and ASR-2 to collect water quality data and hydraulic data

INTERVAL	WELL	WATER QUALITY		
		Chloride (mg/L)	TDS (mg/L)	(μmhos/cm)
785 - 805	ASR-1[B]	6,400	12,000	16,600
806 - 823	ASR-2	4,560	9,070	13,200
900 - 920	ASR-1[B]	12,800	23,400	32,400
944 - 960	ASR-2	13,500	22,000	35,000
978 - 994	ASR-2	14,000	24,600	35,700
1,005 - 1,025	ASR-1[B]	14,200	24,900	34,600
1,012 - 1,028	ASR-2	14,700	25,500	36,700
1,030 - 1,046	ASR-2	14,600	26,900	36,800
1,075 - 1,125[A]	ASR-2	12,500	18,800	30,100
1,105 - 1,125	ASR-1[B]	14,500	25,600	35,600
1,125 - 1,225[A]	ASR-2	15,100	25,500	35,800
1,225 - 1,350[A]	ASR-2	17,600	28,800	42,600

FDEP requested additional testing at ASR-2 to confirm hydrogeologic conditions

INTERVAL (depth in feet)			WELL	HYDRAULIC CONDUCTIVITY	
				Vertical Conductivity (cm/sec)	Horizontal Conductivity (cm/sec)
810.00	to	810.33	ASR-2	1.7×10^{-5}	1.3×10^{-5}
811.00	to	811.33	ASR-2	6.0×10^{-9}	9.2×10^{-9}
813.00	to	813.33	ASR-2	1.3×10^{-8}	2.1×10^{-8}
815.00	to	815.33	ASR-2	4.8×10^{-8}	6.7×10^{-8}
965.00	to	965.33	ASR-2	1.3×10^{-4}	1.9×10^{-4}
981.00	to	981.33	ASR-2	1.0×10^{-3}	4.1×10^{-5}
985.00	to	985.33	ASR-2	8.6×10^{-5}	1.2×10^{-4}
989.00	to	989.33	ASR-2	9.0×10^{-4}	2.5×10^{-3}
991.00	to	991.33	ASR-2	5.4×10^{-4}	9.9×10^{-4}
994.00	to	994.33	ASR-2	9.3×10^{-6}	1.7×10^{-5}
996.00	to	996.33	ASR-2	2.3×10^{-7}	8.3×10^{-7}
1,013.00	to	1,013.33	ASR-2	1.3×10^{-4}	3.4×10^{-4}
1,015.00	to	1,015.33	ASR-2	4.6×10^{-6}	1.3×10^{-3}
1,024.00	to	1,024.33	ASR-2	2.3×10^{-6}	8.2×10^{-6}
1,025.00	to	1,025.33	ASR-2	1.3×10^{-6}	3.1×10^{-5}
1,068.00	to	1,068.33	ASR-2	4.3×10^{-6}	6.8×10^{-5}
1,115.00	to	1,115.33	ASR-2	7.0×10^{-8}	6.4×10^{-8}
1,116.00	to	1,116.33	ASR-2	6.8×10^{-8}	6.9×10^{-8}

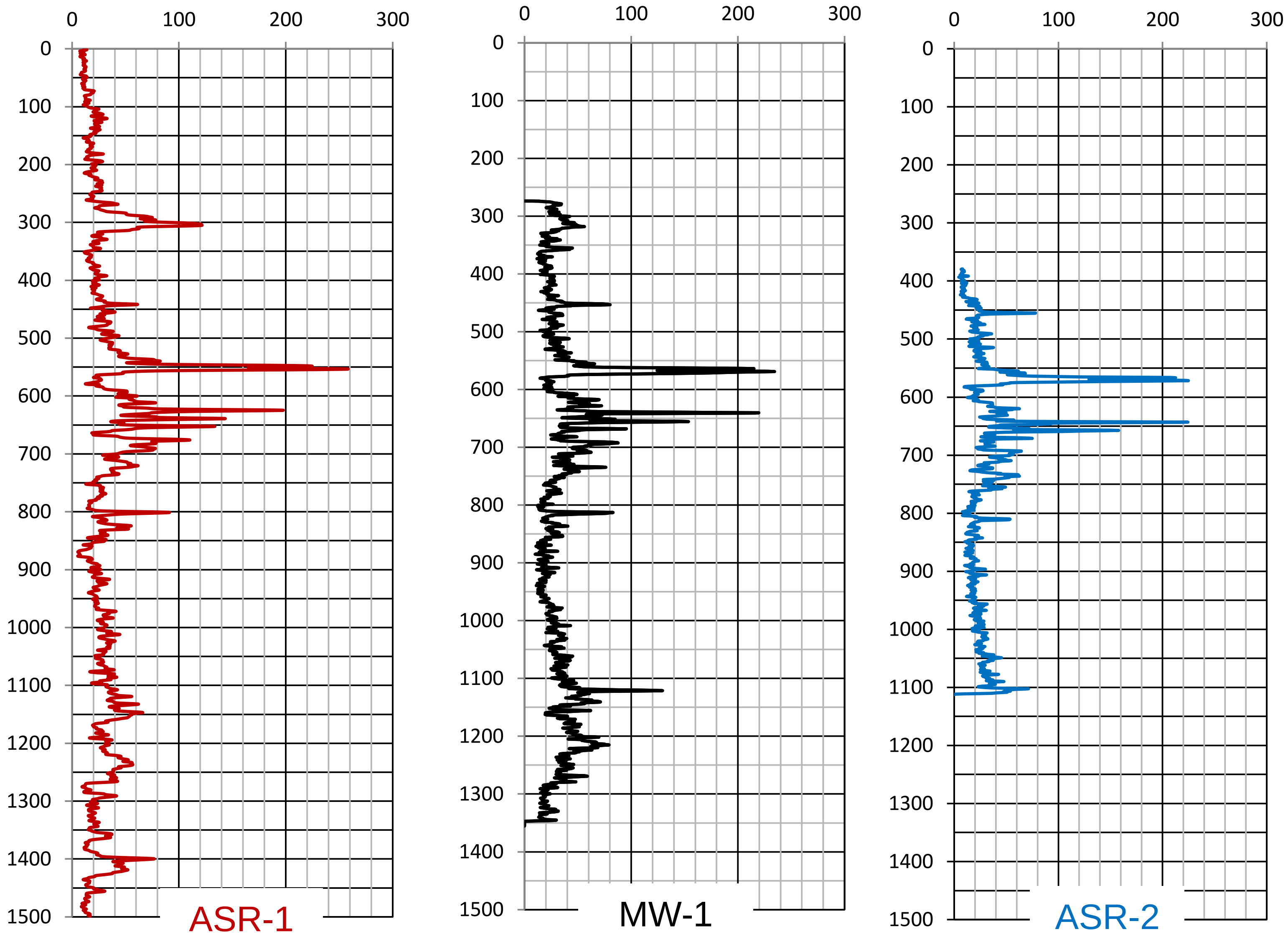
Coring used to confirm confinement

HAZEN AND SAWYER
Environmental Engineers & Scientists

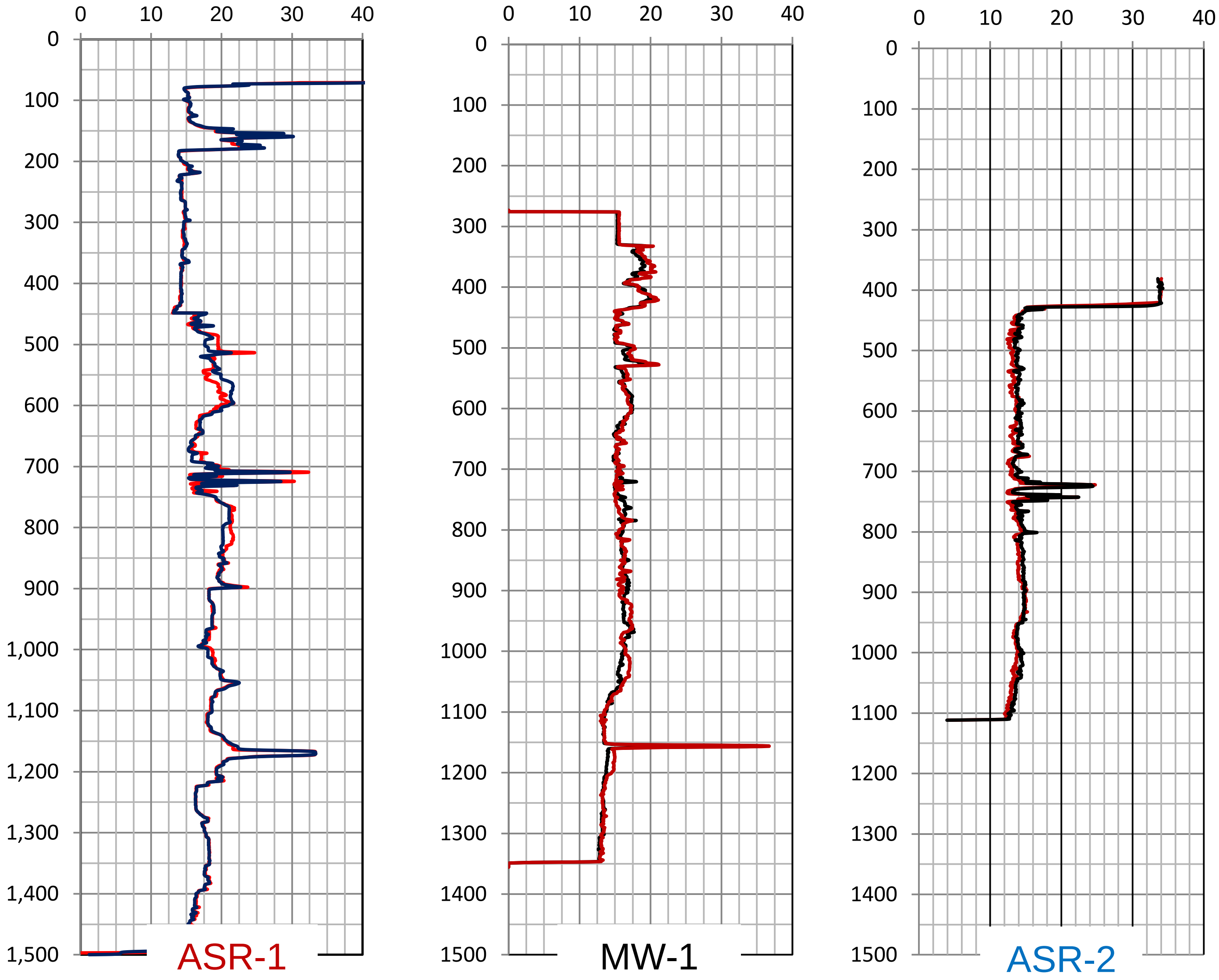
Additional testing at ASR-2 confirmed presence of confinement and aquifer characteristics

- Core test results from ASR-2
  - Cored interval from 780 to 1,080 feet
  - Average vertical conductivity 1.62 x 10^{-4}

- Storage zone characteristics
  - Transmissivity (35,000 to 200,000 gpd/ft)
  - Specific capacity
    - ASR-1 ~ 115 gpm/ft
    - ASR-2 ~ 65 gpm/ft



Comparison of geophysical data (Gamma Ray) confirmed consistency of underground conditions



Review of borehole characteristics also confirmed consistency of underground conditions (Caliper Log)

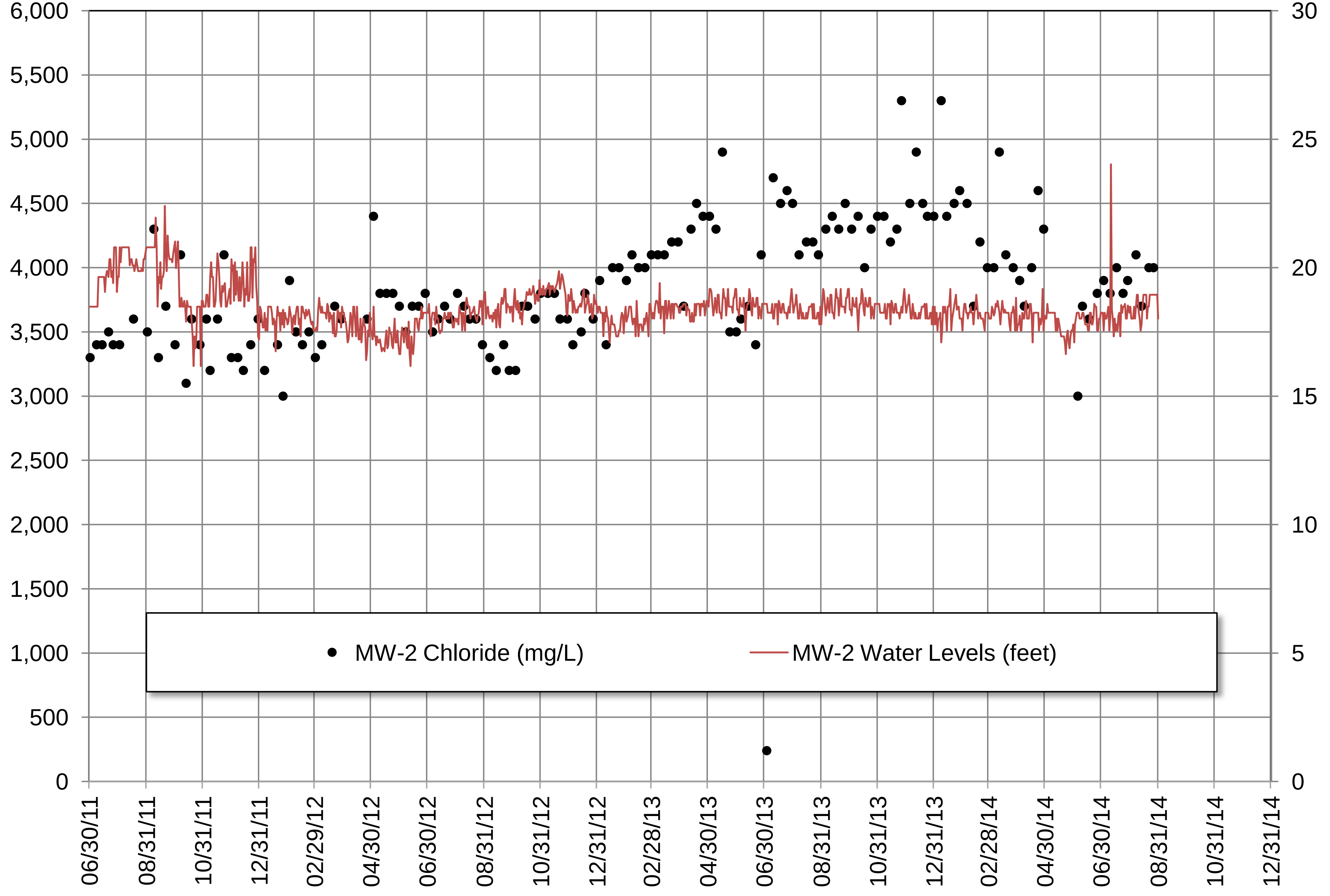
Develop a cost effective strategy that maximizes reclaimed water usage

Project approach and methodology

- Consistency with Integrated Water Resources Plan
- Build on existing facilities
- Apply lessons learned
- Maximize opportunities
- Seek innovative cost effective solutions

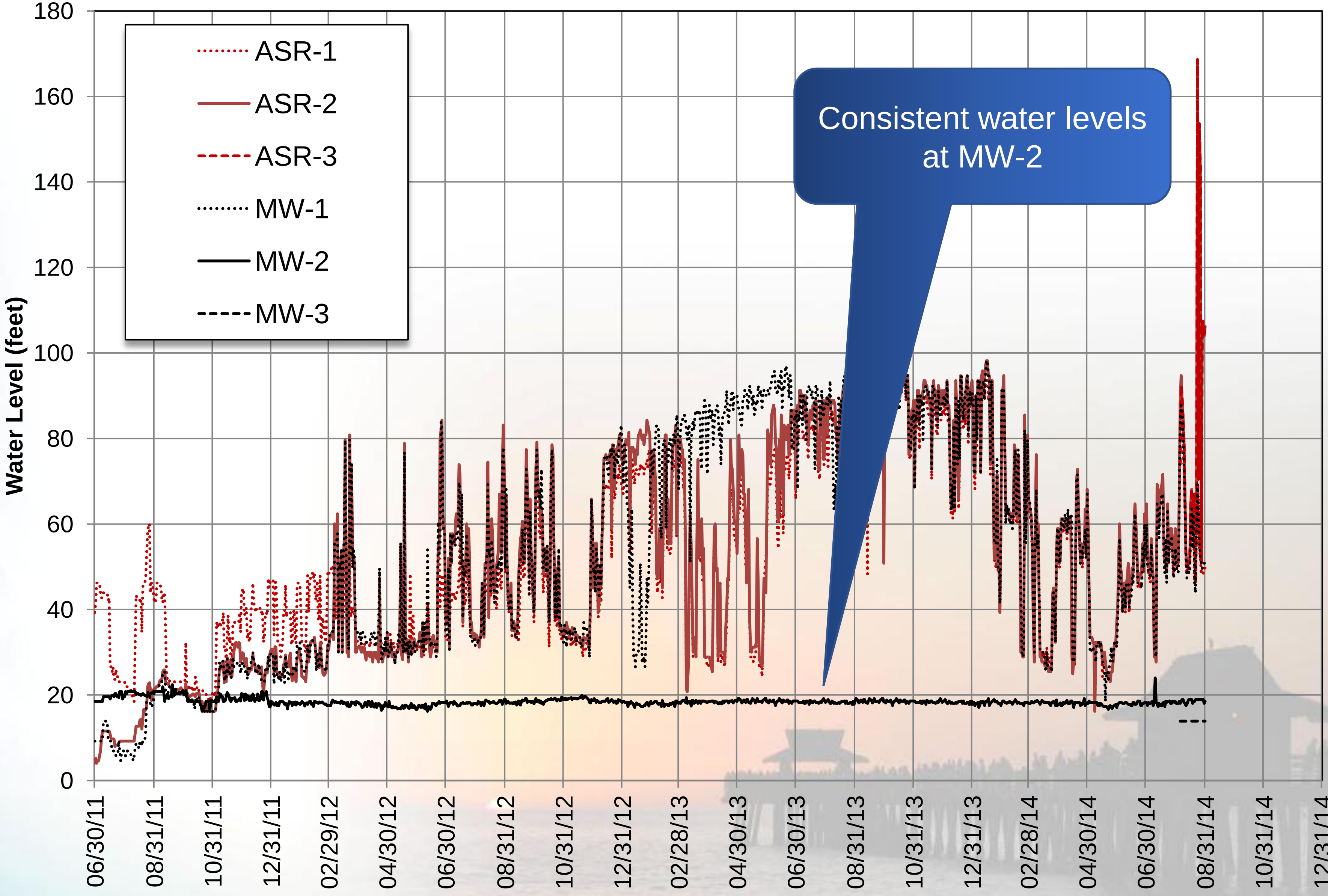
Think of low fruit opportunities to minimize expenditures

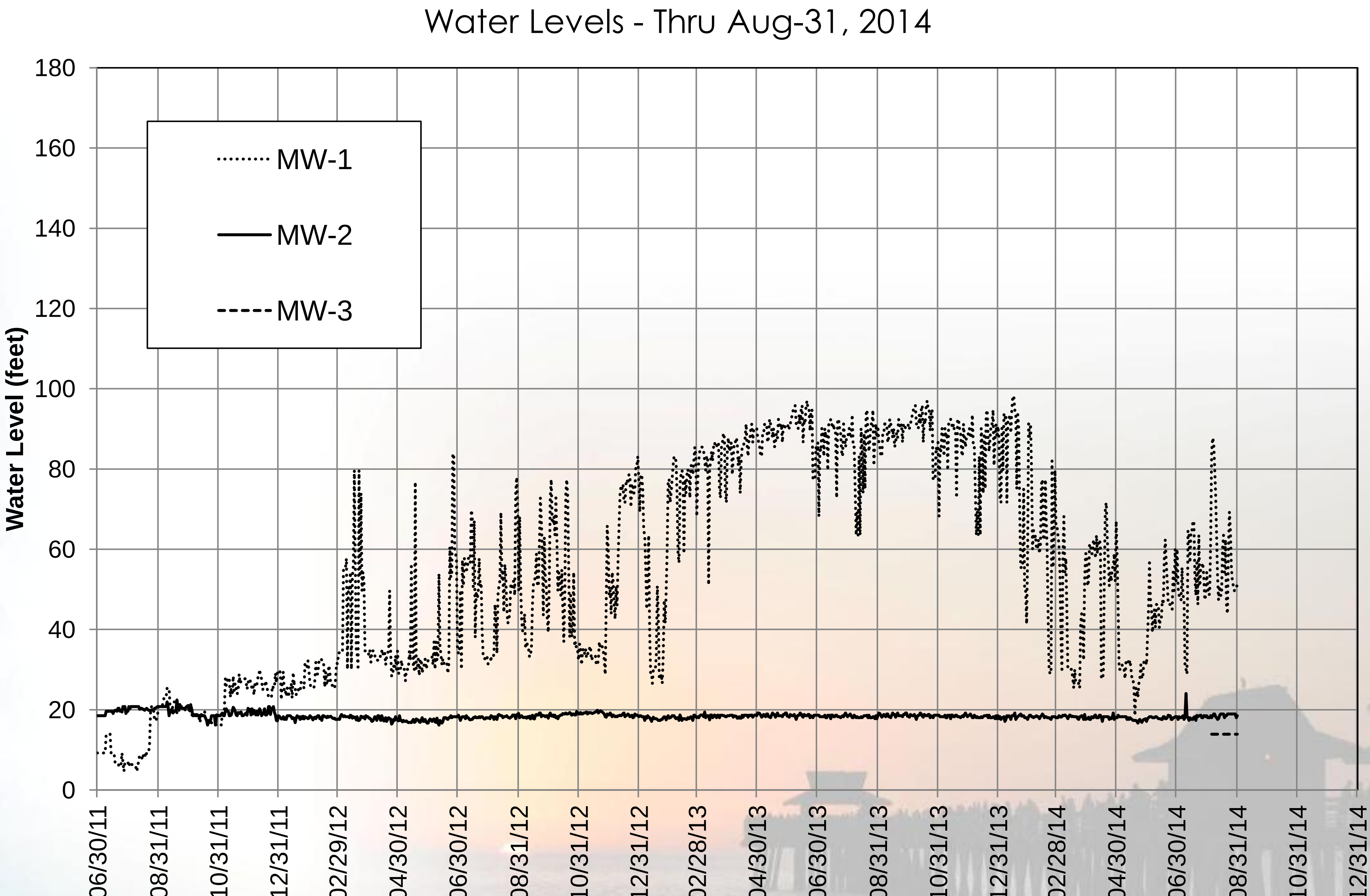
System performance measured by monitoring system



41000-007

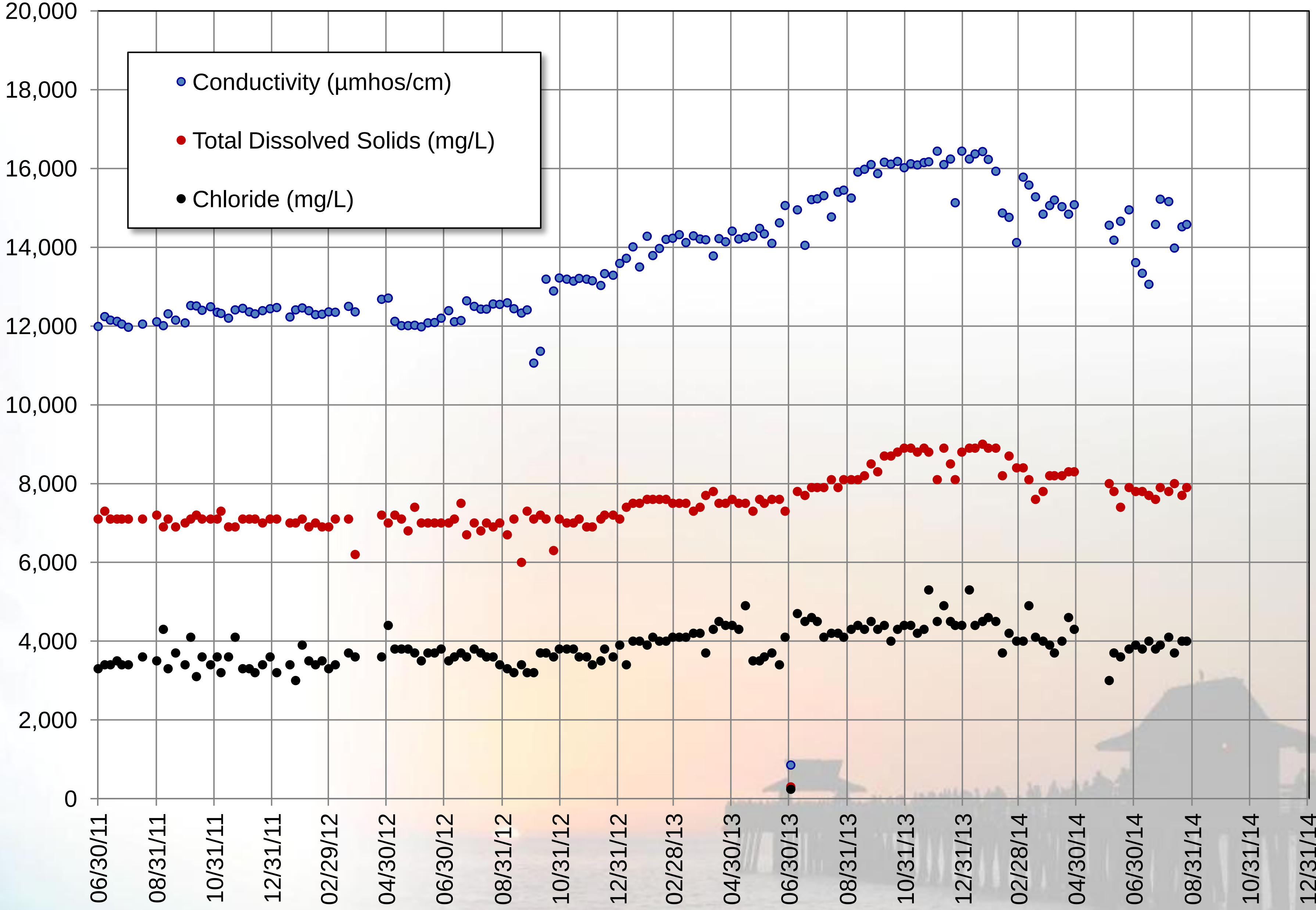
Water Levels - Thru Aug-31, 2014




Water Levels - Thru Aug-31, 2014
Water Level (feet)
180
160
140
120
100
80
60
40
20
0
MW-1
MW-2
MW-3
06/30/11
08/31/11
10/31/11
12/31/11
02/29/12
04/30/12
06/30/12
08/31/12
10/31/12
12/31/12
02/28/13
04/30/13
06/30/13
08/31/13
10/31/13
12/31/13
02/28/14
04/30/14
06/30/14
08/31/14
10/31/14
12/31/14

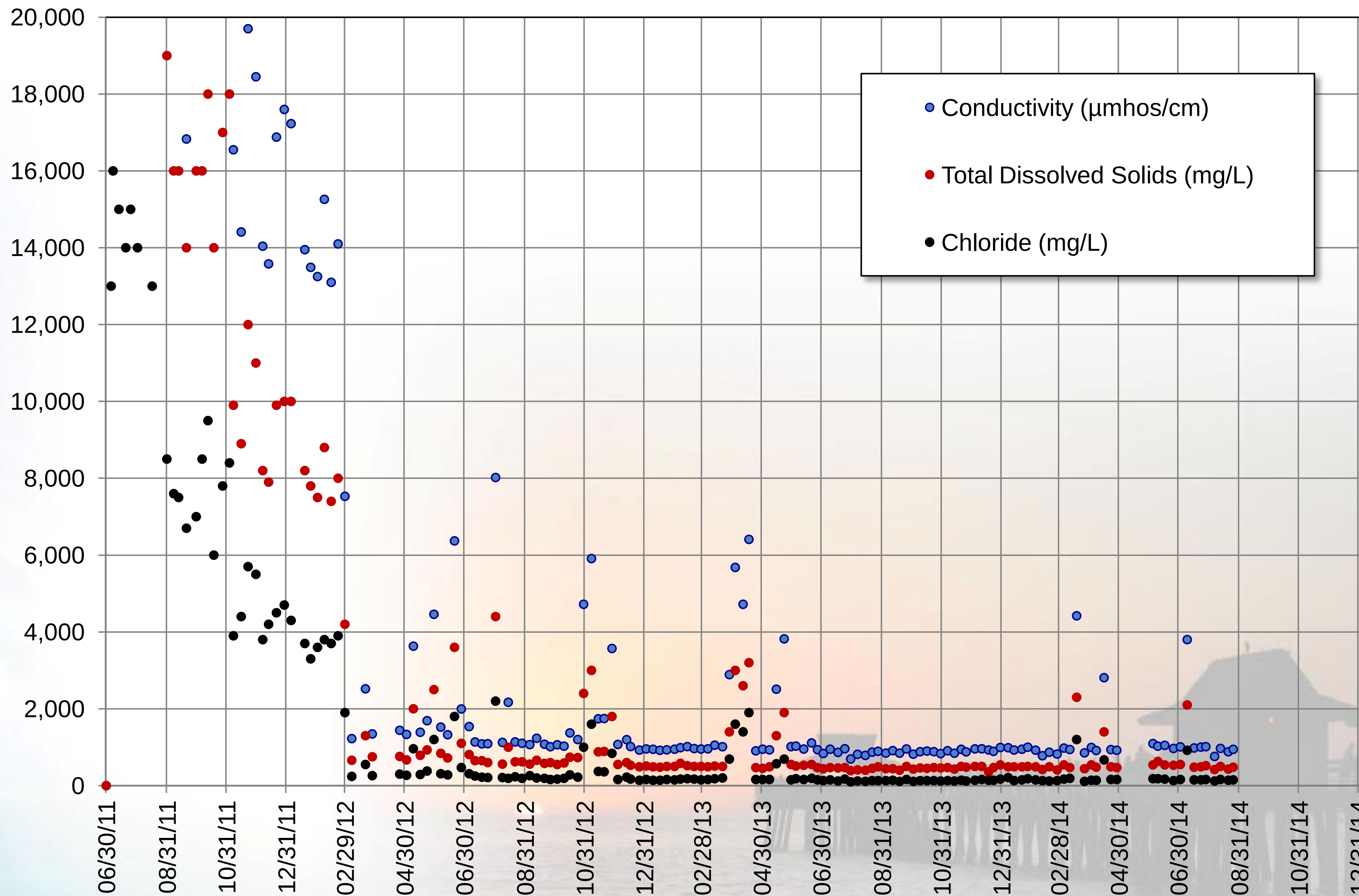
41000-007

Water quality at MW-2 also used to monitor performance



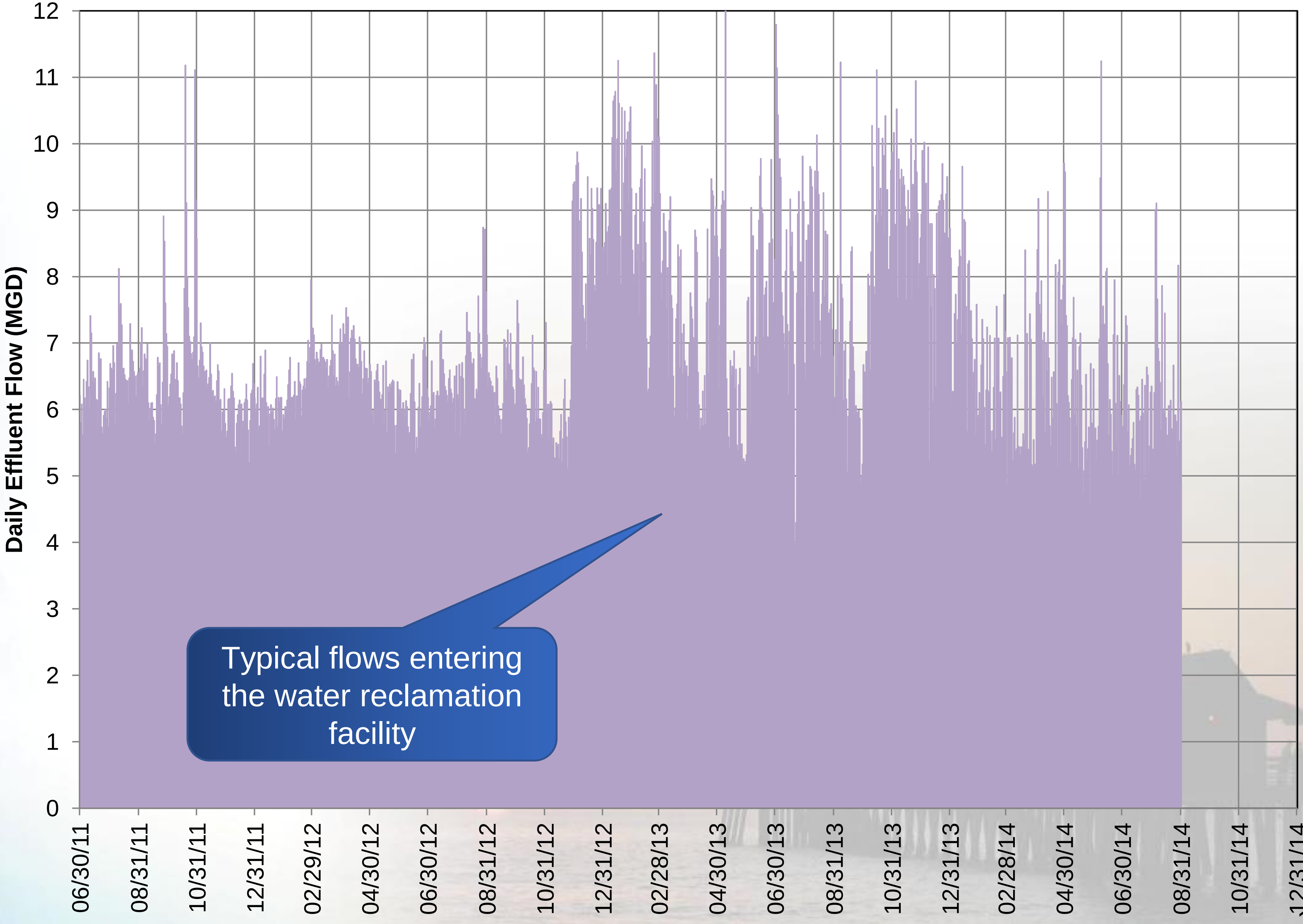
41000-007

Monitor Well No. 1 - Water Quality



41000-007

Daily Effluent Flow



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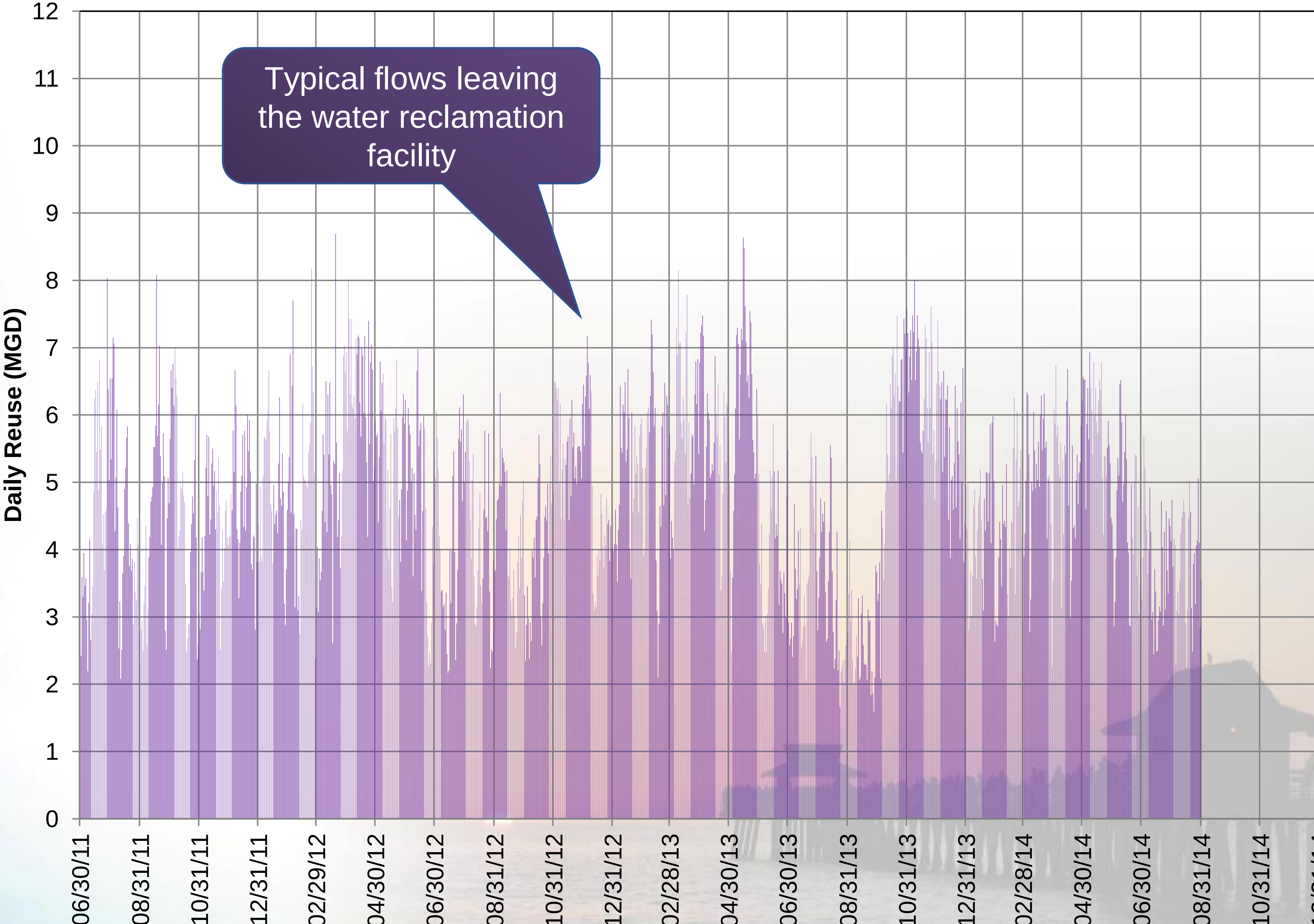
Daily Reuse



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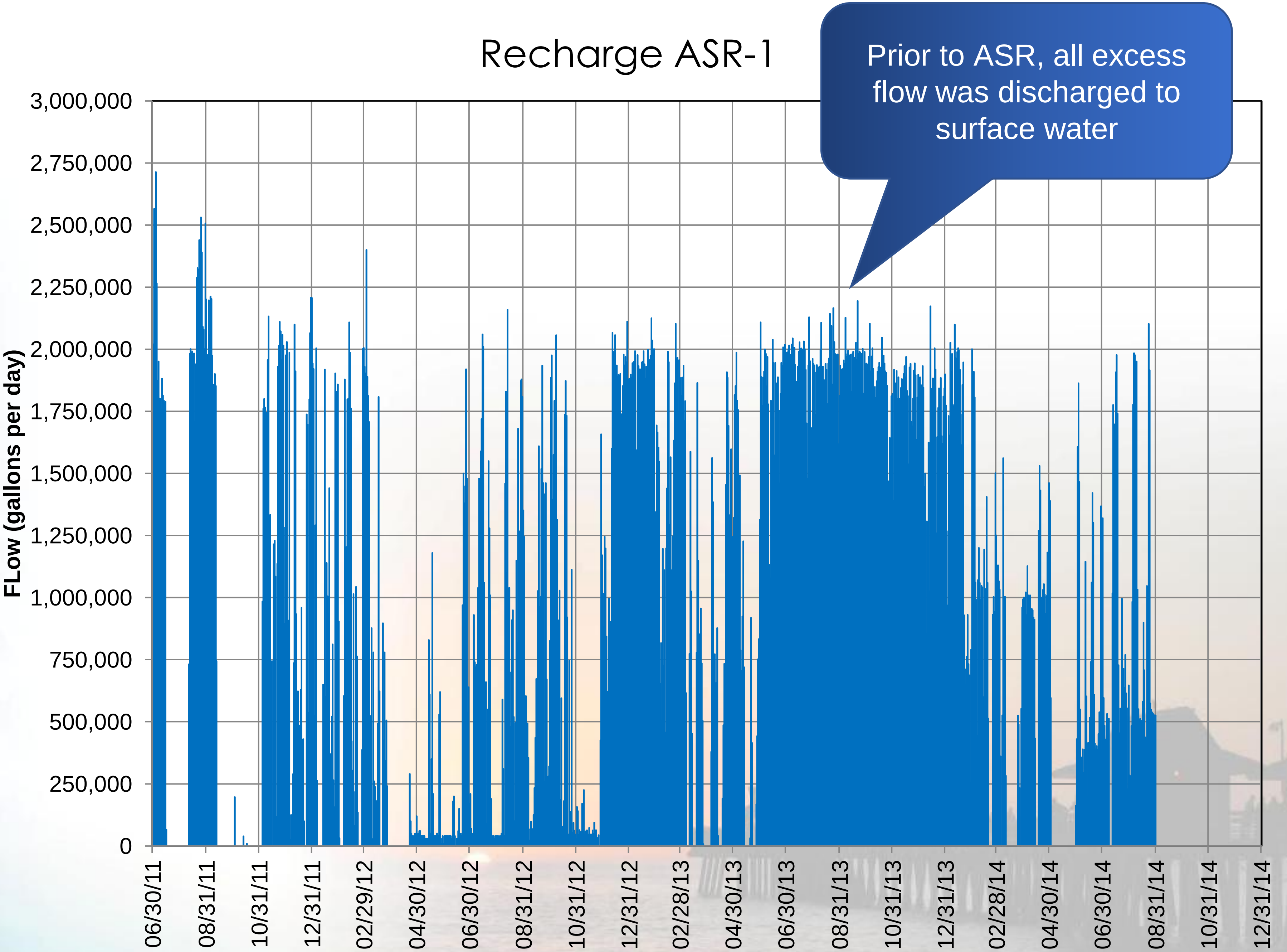

Recharge ASR-1
Prior to ASR, all excess flow was discharged to surface water
FLow (gallons per day)
3,000,000
2,750,000
2,500,000
2,250,000
2,000,000
1,750,000
1,500,000
1,250,000
1,000,000
750,000
500,000
250,000
0
06/30/11
08/31/11
10/31/11
12/31/11
02/29/12
04/30/12
06/30/12
08/31/12
10/31/12
12/31/12
02/28/13
04/30/13
06/30/13
08/31/13
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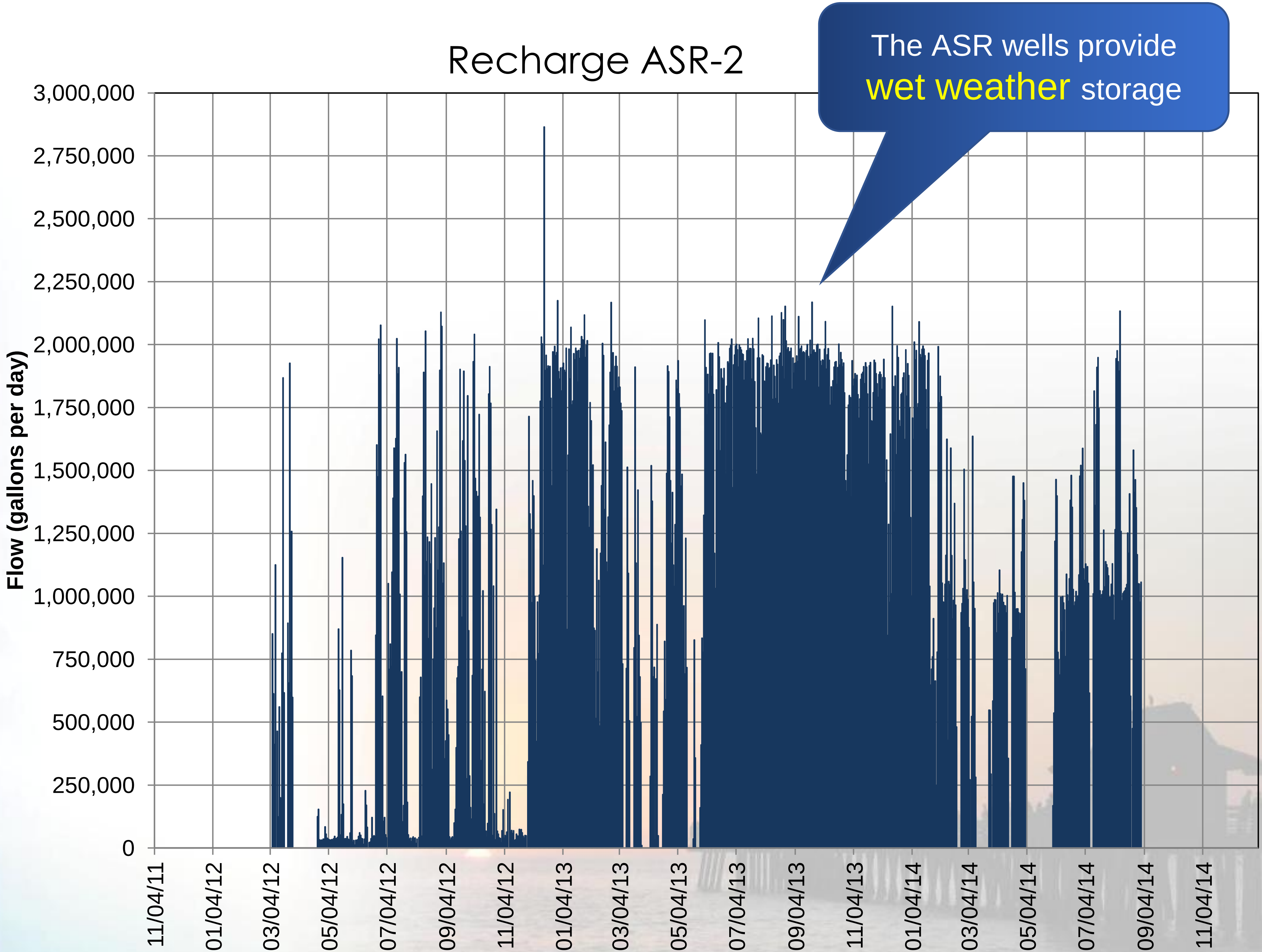
12/31/14

41000-007


Recharge ASR-2
The ASR wells provide wet weather storage
Flow (gallons per day)
3,000,000
2,750,000
2,500,000
2,250,000
2,000,000
1,750,000
1,500,000
1,250,000
1,000,000
750,000
500,000
250,000
0
11/04/11
01/04/12
03/04/12
05/04/12
07/04/12
09/04/12
11/04/12
01/04/13
03/04/13
05/04/13
07/04/13
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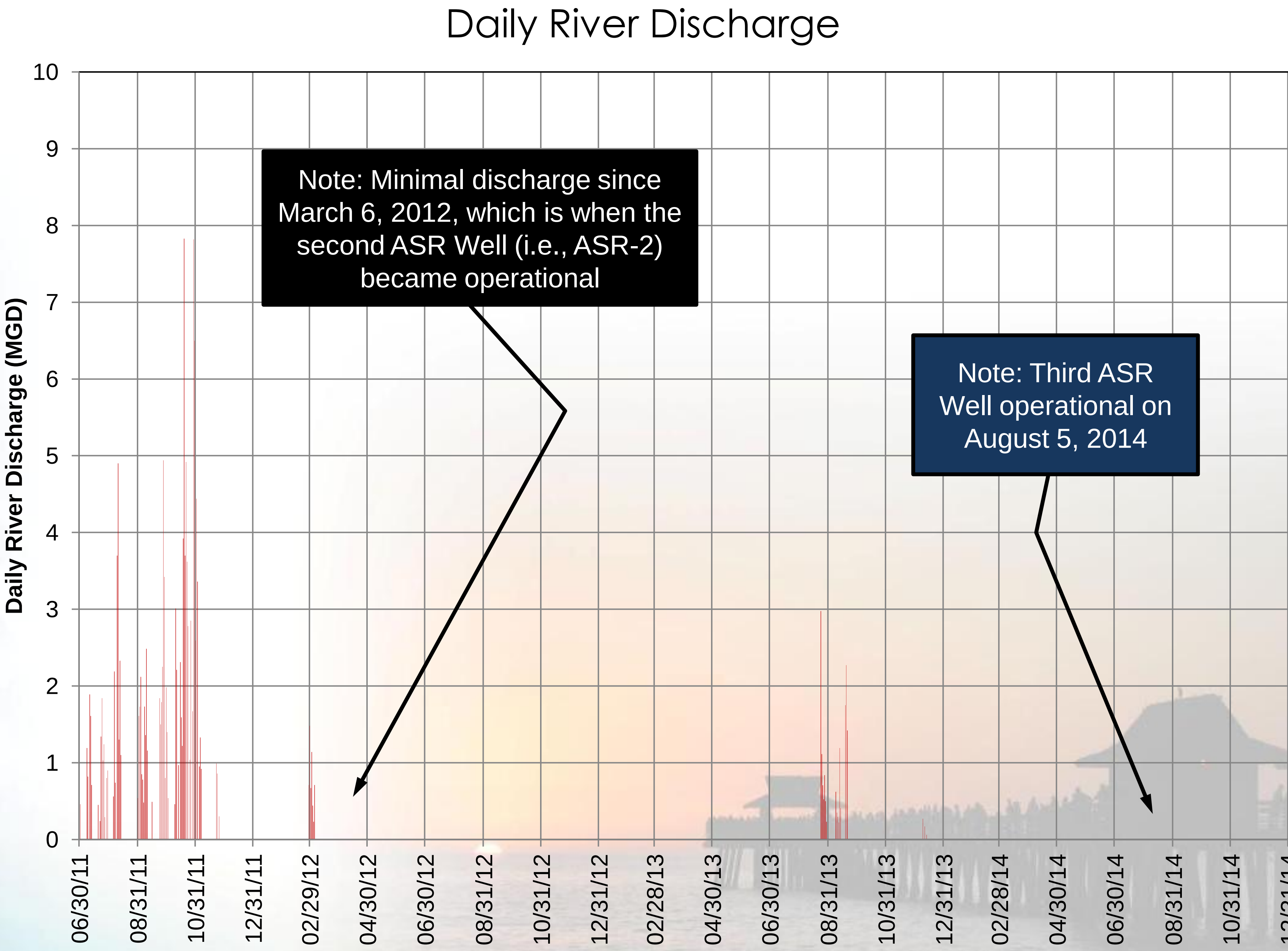
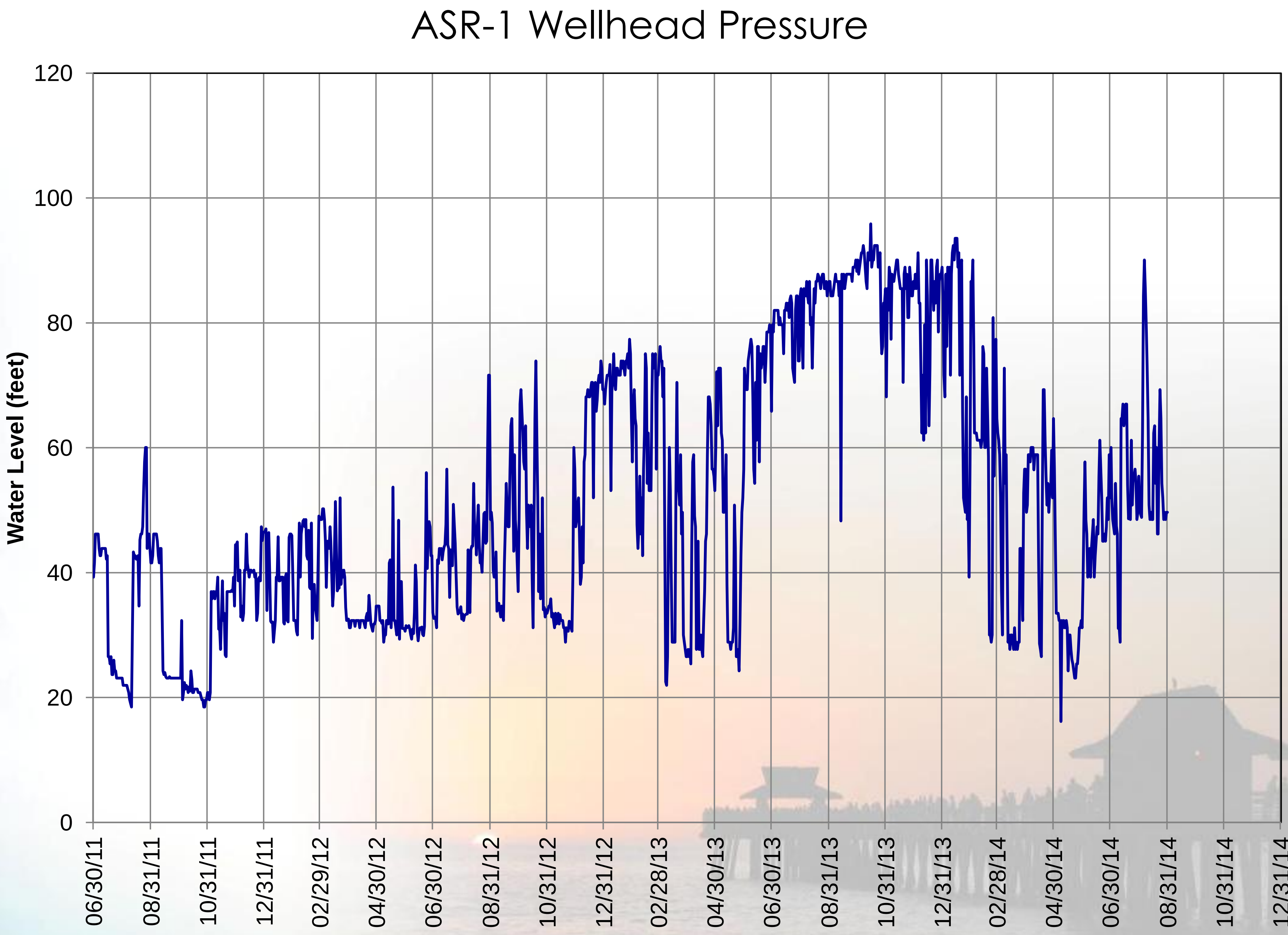
07/04/14
09/04/14
11/04/14

41000-007


Daily River Discharge
Daily River Discharge (MGD)
0
1
2
3
4
5
6
7
8
9
10
06/30/11
08/31/11
10/31/11
12/31/11
02/29/12
04/30/12
06/30/12
08/31/12
10/31/12
12/31/12
02/28/13
04/30/13
06/30/13
08/31/13
10/31/13
12/31/13
02/28/14
04/30/14
06/30/14
08/31/14
10/31/14
12/31/14
Note: Minimal discharge since March 6, 2012, which is when the second ASR Well (i.e., ASR-2) became operational
Note: Third ASR Well operational on August 5, 2014

41000-007


ASR-1 Wellhead Pressure
Water Level (feet)
0
20
40
60
80
100
120
06/30/11
08/31/11
10/31/11
12/31/11
02/29/12
04/30/12
06/30/12
08/31/12
10/31/12
12/31/12
02/28/13
04/30/13
06/30/13
08/31/13
10/31/13
12/31/13
02/28/14
04/30/14
06/30/14
08/31/14
10/31/14
12/31/14

41000-007

ASR-2 Wellhead Pressure