


Ephemeral Arsenic: Two Years, Three Cycles at Kissimmee River ASR Pilot Site Show "Natural Attenuation" of Arsenic

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American Ground Water Trust ASR11
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Kissimmee River ASR Pilot System, Okeechobee, FL

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- 5 MGD pumping rate
 - Kissimmee River source water – filtered, UV disinfected
 - Storage in upper Floridan Aquifer, 550 – 880 ft bls
 - Three cycle tests completed; 4th underway

Cycle Testing History

January 2009 through June 2011

CYCLE 1

1 month each Recharge,
Storage, and Recovery

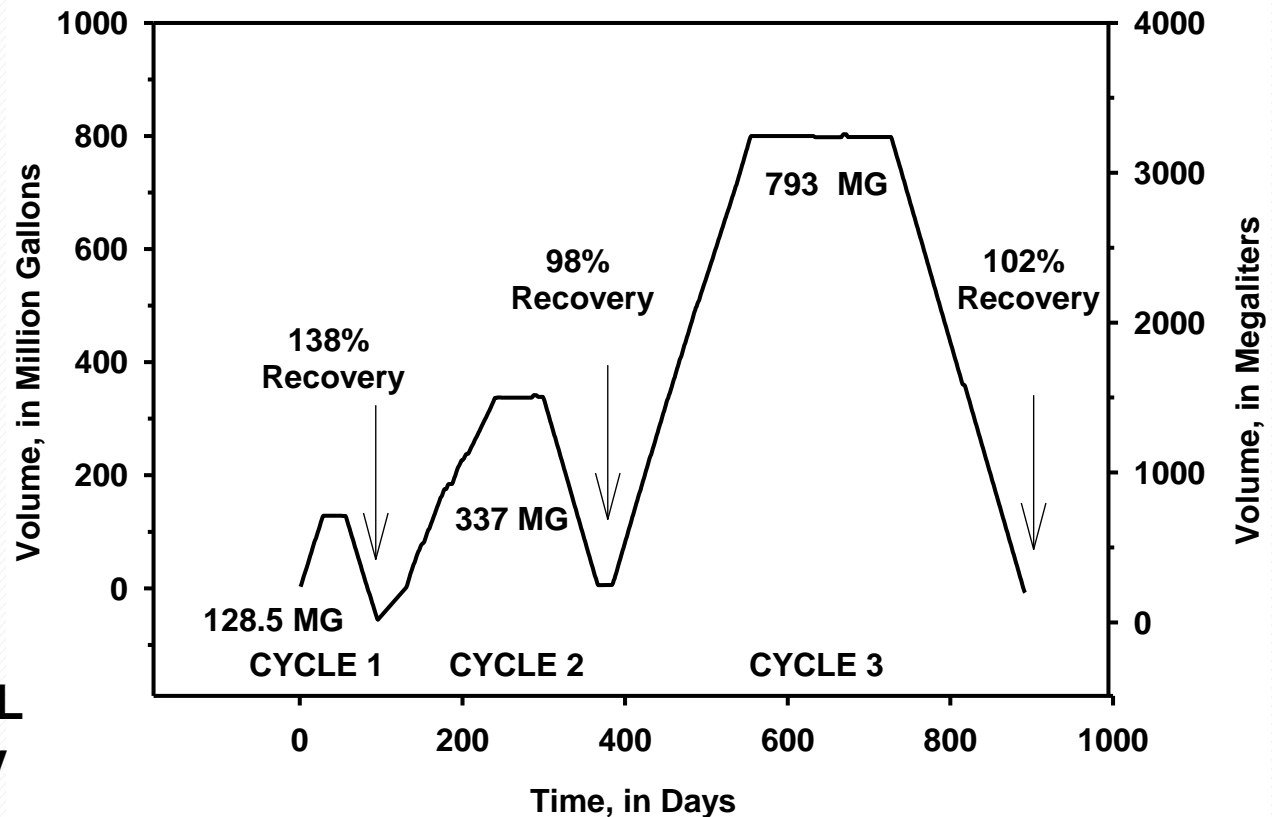
CYCLE 2

3 months each Recharge,
Storage, and Recovery

CYCLE 3

6 months each Recharge,
Storage, and Recovery

Native FAS [Cl-] = 250 mg/L
resulting in 100% recovery
by volume





MONITORING WELLFIELD

- ASR WELL: EXKR-1, 5 MGD
 - **350-FT** STORAGE ZONE
MONITOR WELL: MW-10
 - **1,250-FT** DUAL ZONE
MONITOR WELL: OKF-100
UPPER FAS and APPZ
 - **2,350-FT** STORAGE ZONE
MONITOR WELL: MW-18
 - **4,200-FT** STORAGE ZONE
MONITOR WELL: MW-19
-

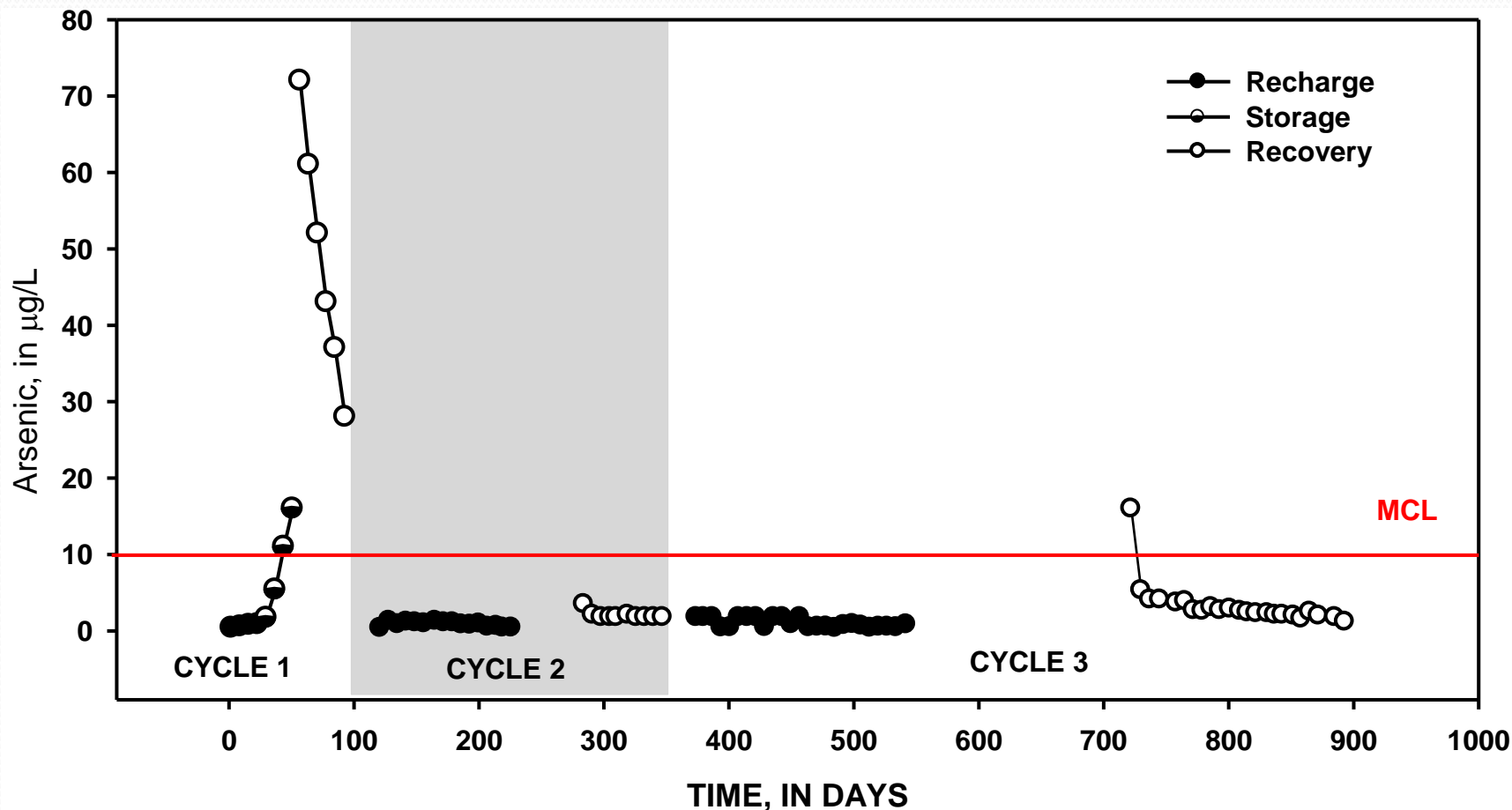
Flowpath extends from
ASR well

➔ 350-ft SZMW

➔ 1250 ft SZMW

Arsenic Trends During 3 Cycles

ASR Well Data



ASR WELL



350-FT SZMW

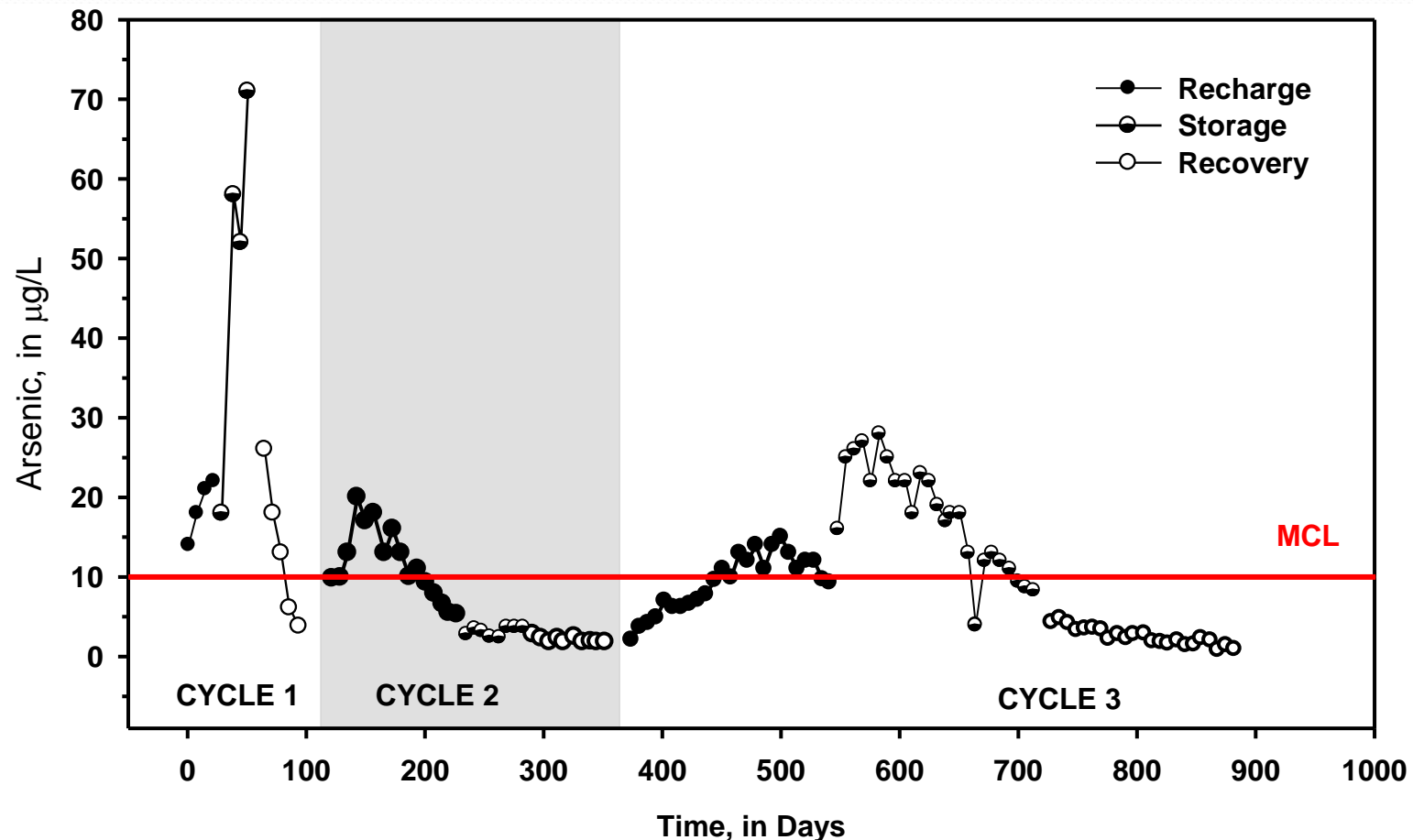


1,250-FT SZMW



Arsenic Trends During 3 Cycles

350-ft SZMW



ASR WELL



350-FT SZMW

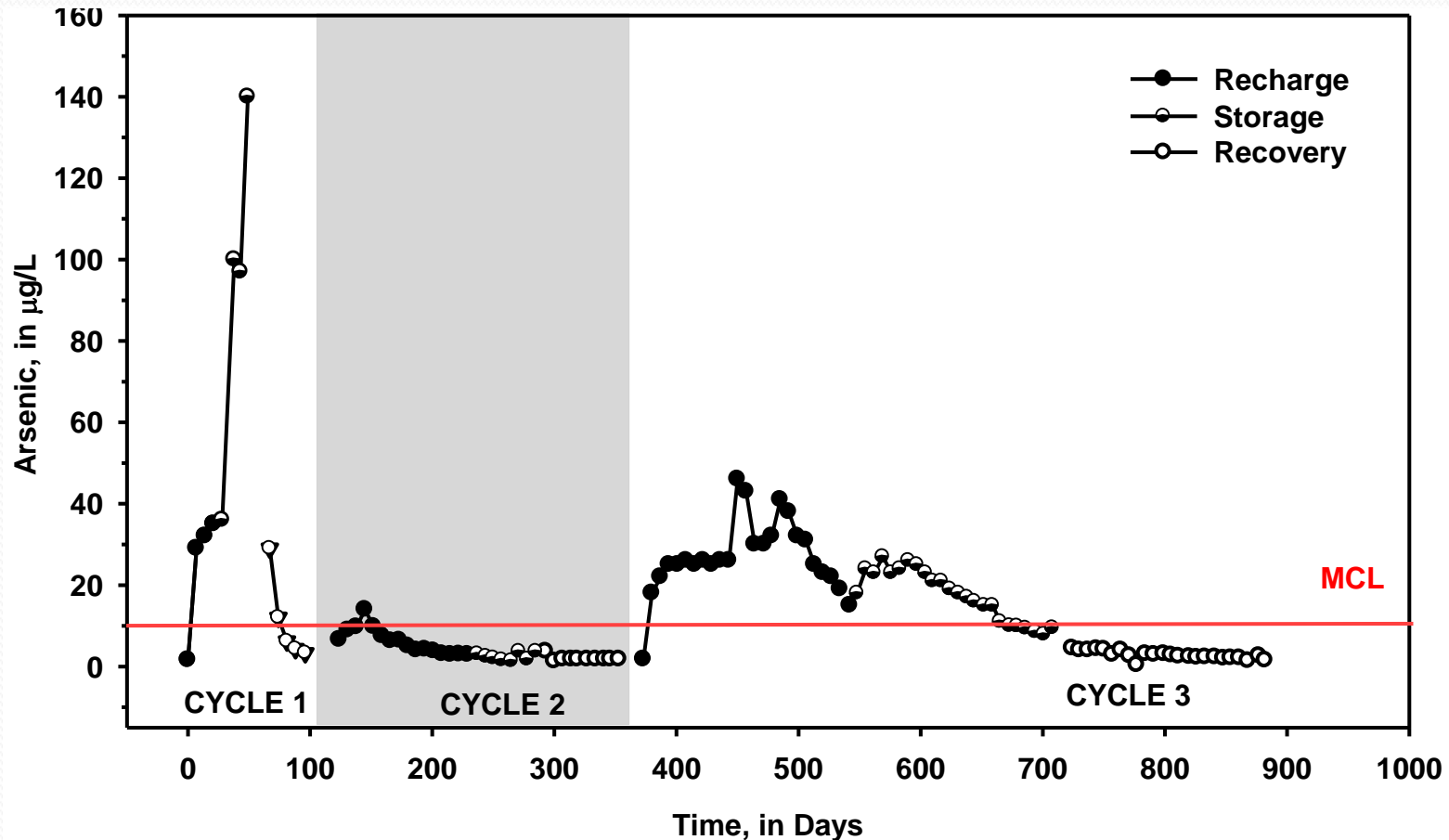


1,250-FT SZMW



Arsenic Trends During 3 Cycles

1,250-ft SZMW



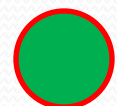
ASR WELL



350-FT SZMW



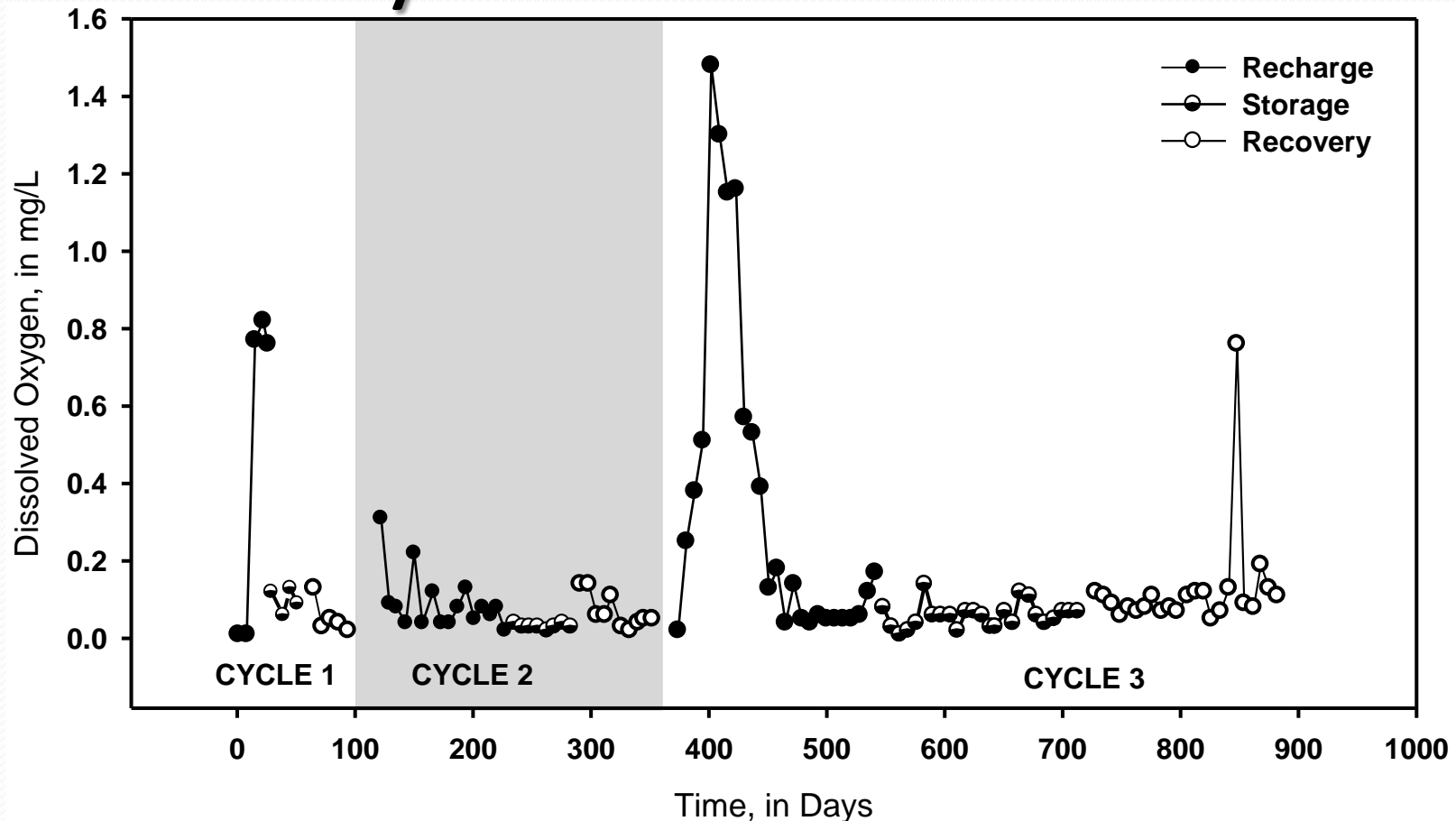
1,250-FT SZMW



Interpretation of Arsenic Trends

- Arsenic concentrations in recovered water were below 10 ppb during cycles 2 and 3
- At 5 MGD pumping rate, arsenic is transported between 1,250 and 2,350 ft away from the ASR well **TENTATIVE** pending analysis of aquifer anisotropy at this site.
- Arsenic is mobilized during recharge, but concentrations decline in the aquifer as a result of geochemical reactions

Dissolved Oxygen Trends During 3 Cycles: 350-ft SZMW



ALL SAMPLES COLLECTED AFTER 3 PURGE VOLUMES IN A FLOW-THROUGH CHAMBER AT THE WELLHEAD

ASR WELL



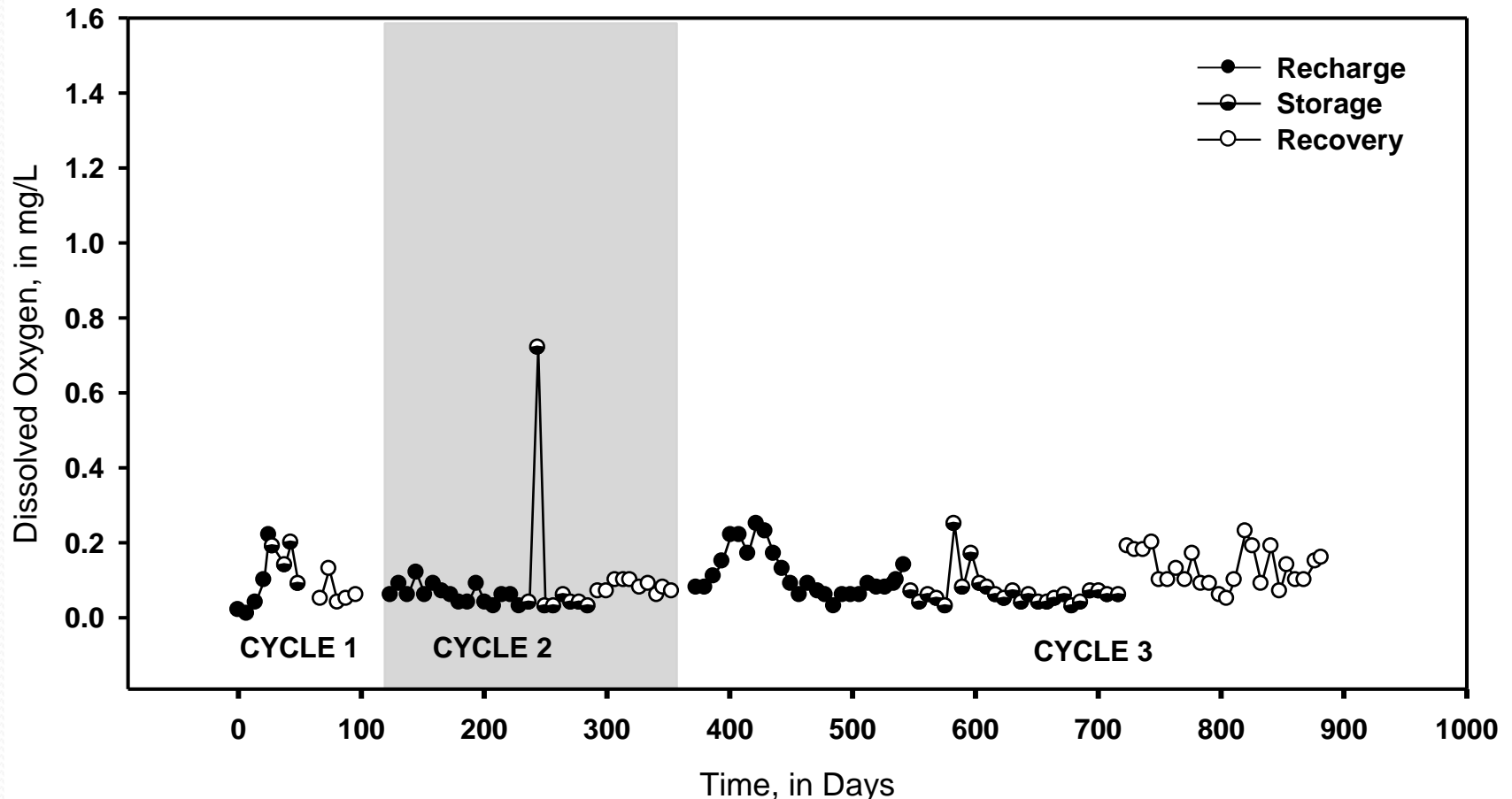
350-FT SZMW



1,250-FT SZMW



Dissolved Oxygen Trends During 3 Cycles: 1,250-ft SZMW



ALL SAMPLES COLLECTED AFTER 3 PURGE VOLUMES IN A FLOW-THROUGH CHAMBER AT THE WELLHEAD

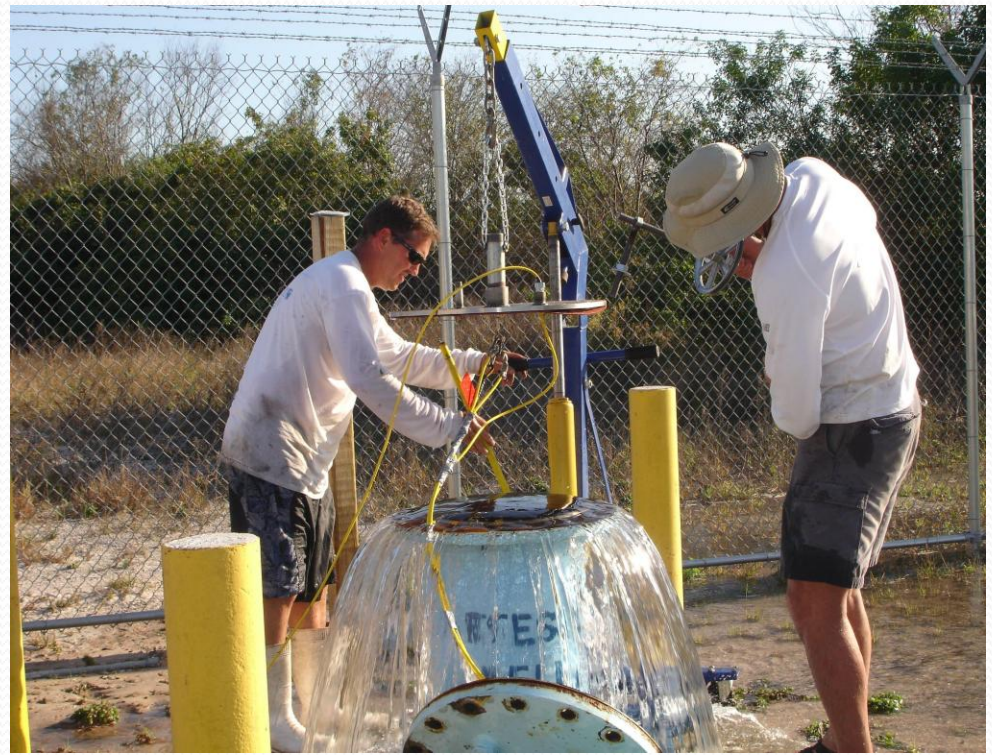
ASR WELL

350-FT SZMW

1,250-FT SZMW



SeaBird Probe in 350-ft SZMW (MW-10)



Parameters:

Temperature

Pressure

Specific Conductance

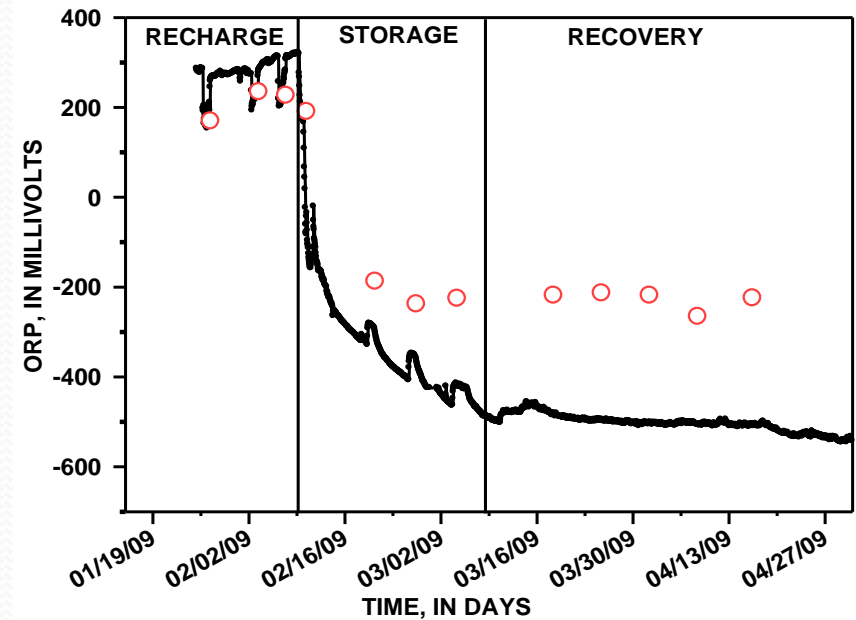
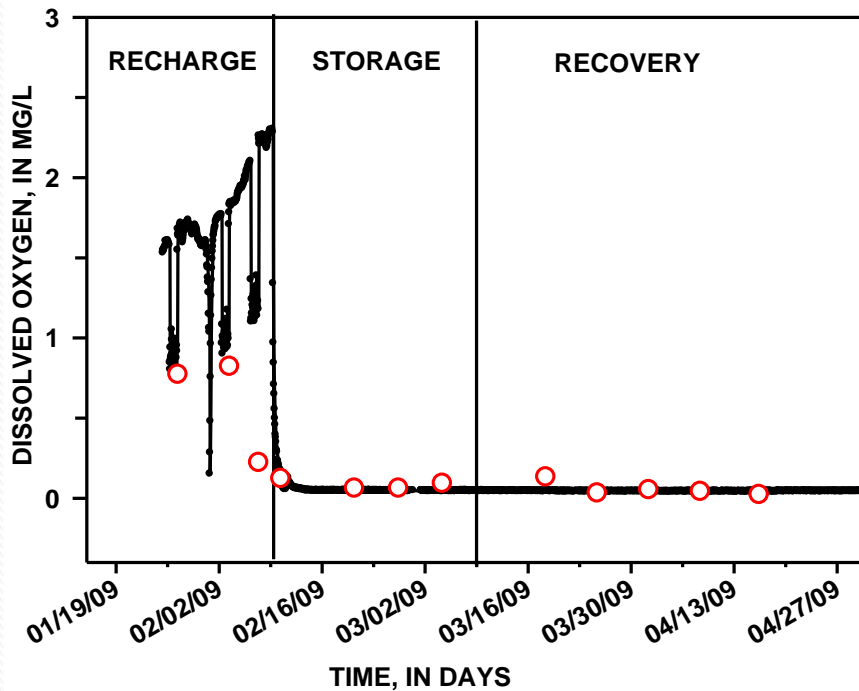
pH

Dissolved Oxygen

ORP

How Long Do Oxidic Conditions Persist During ASR Cycle Testing?

— PROBE DATA
○ WELLHEAD DATA



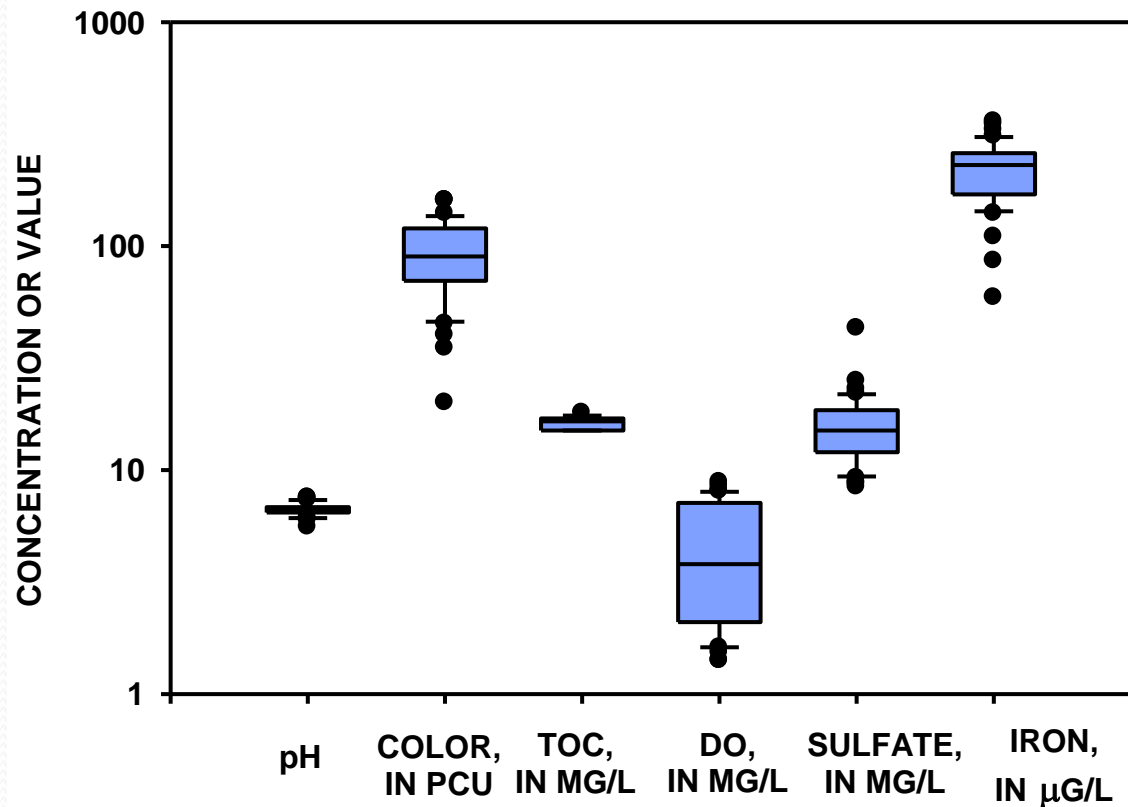
CYCLE 1, SeaBird Probe data in 350-ft SZMW

Half-life of dissolved oxygen after recharge ends: Approximately 25 hours

Interpretation of Dissolved Oxygen Trends

- Dissolved Oxygen concentrations diminish during transport, and deplete rapidly when pumping ceases, with a 25-hour half-life.
- At 5 MGD pumping rate, dissolved oxygen is transported between 350 ft and 1,250 ft away from the ASR well
- In-situ measurements of dissolved oxygen in the storage zone are slightly greater than wellhead measurements
- Aquifer redox condition evolves to a reducing condition as dissolved oxygen is depleted

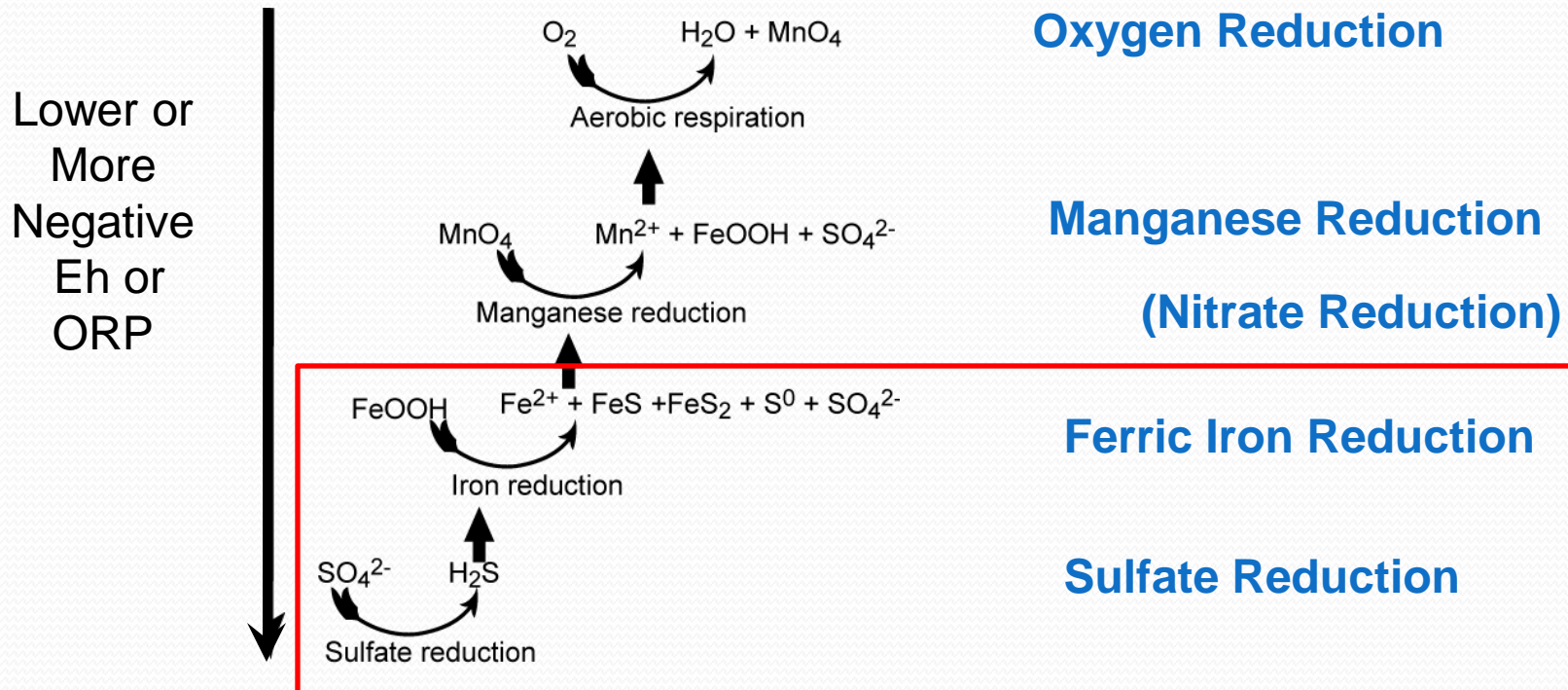
Recharge Water Quality: Kissimmee River Source Water



MEDIAN	6.62	90	16	4.51	15.5	230
STD DEV	0.42	33	1	2	6	67
N	42	41	14	42	41	42

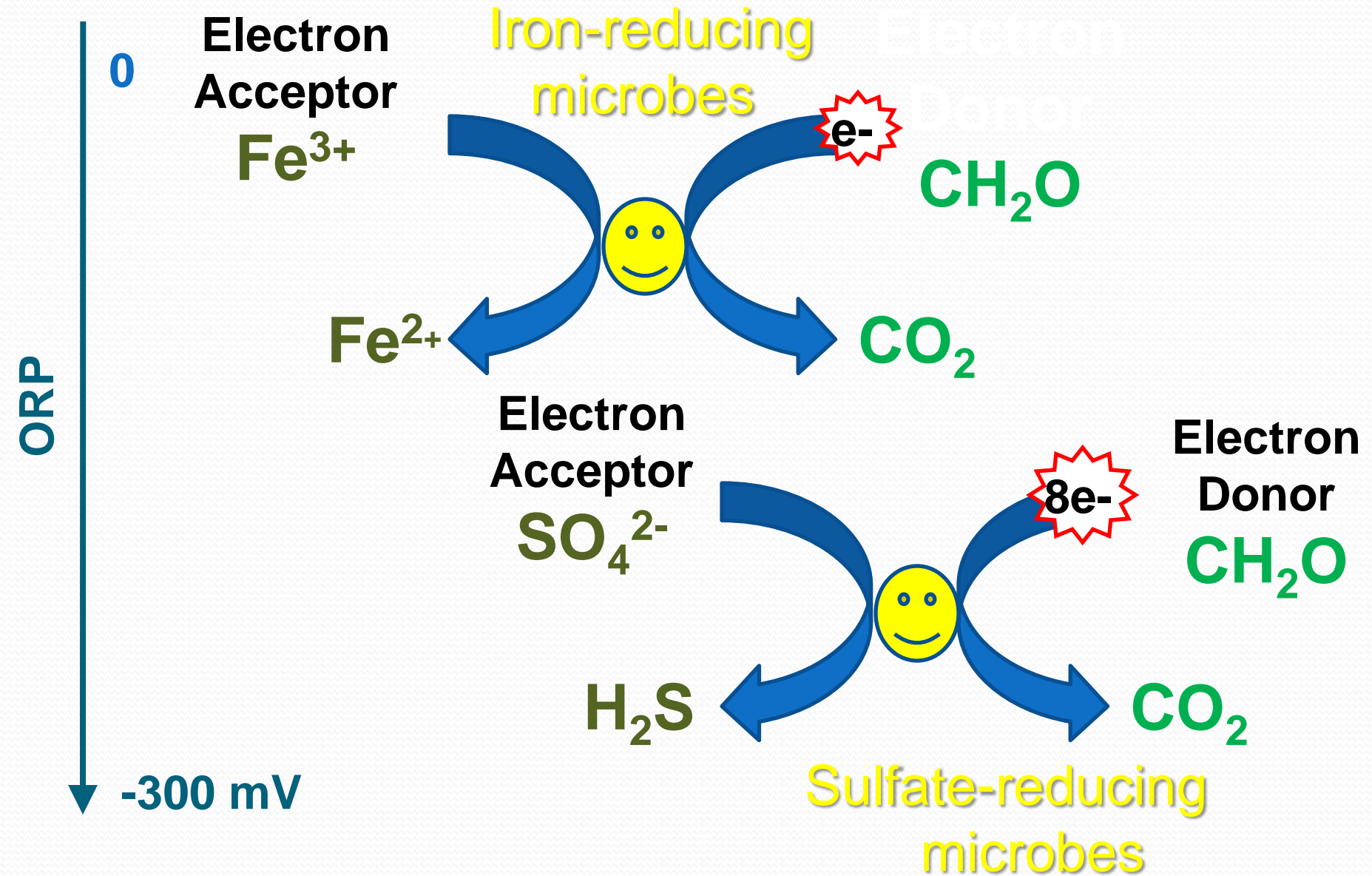
Redox Control of Arsenic Mobility During ASR Cycle Testing

- Pyrite (Iron Sulfide) in FAS aquifer matrix is the source of arsenic
- Pyrite is a stable solid mineral in native FAS



- Arsenic is released by pyrite oxidation during recharge
- Control pyrite oxidation, and you can control arsenic

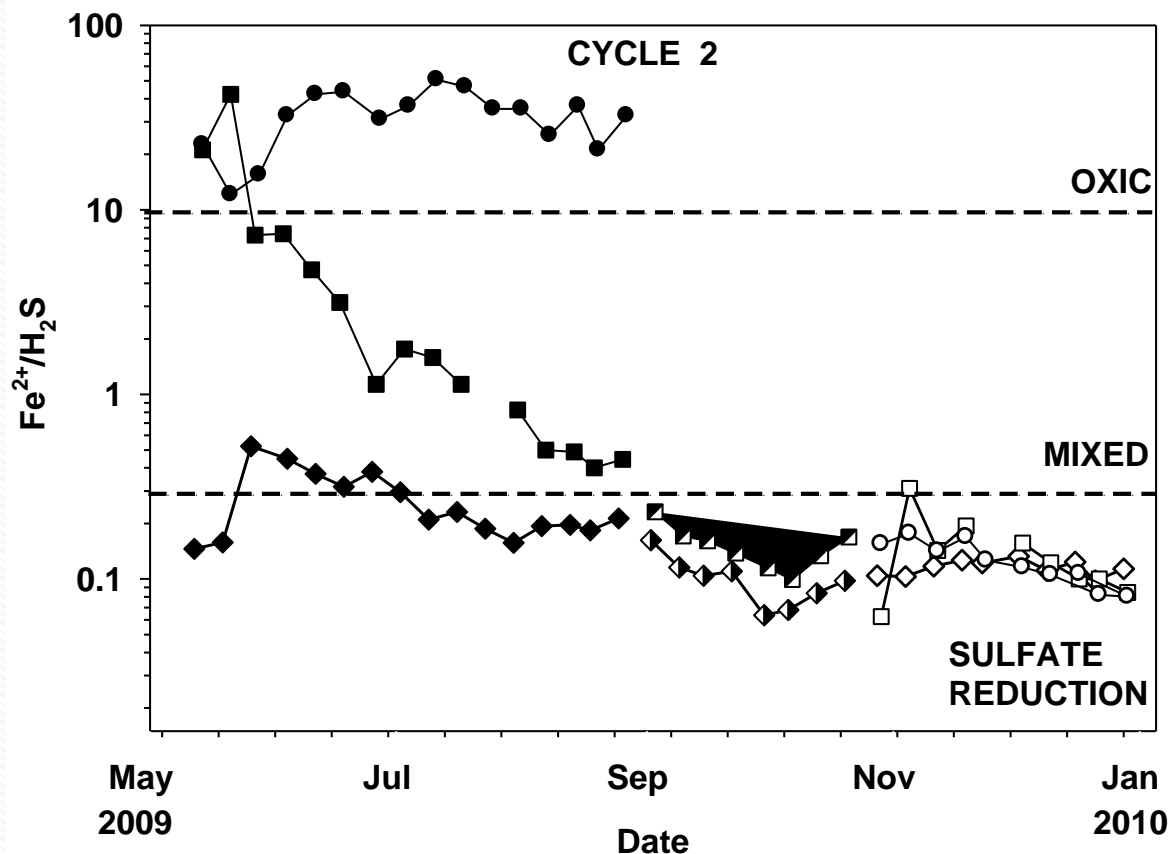
Microbe-Mediated Redox Couples



Framboidal and Crystalline Pyrite in Suwannee Limestone



Redox Evolution During ASR Cycle Testing



A.

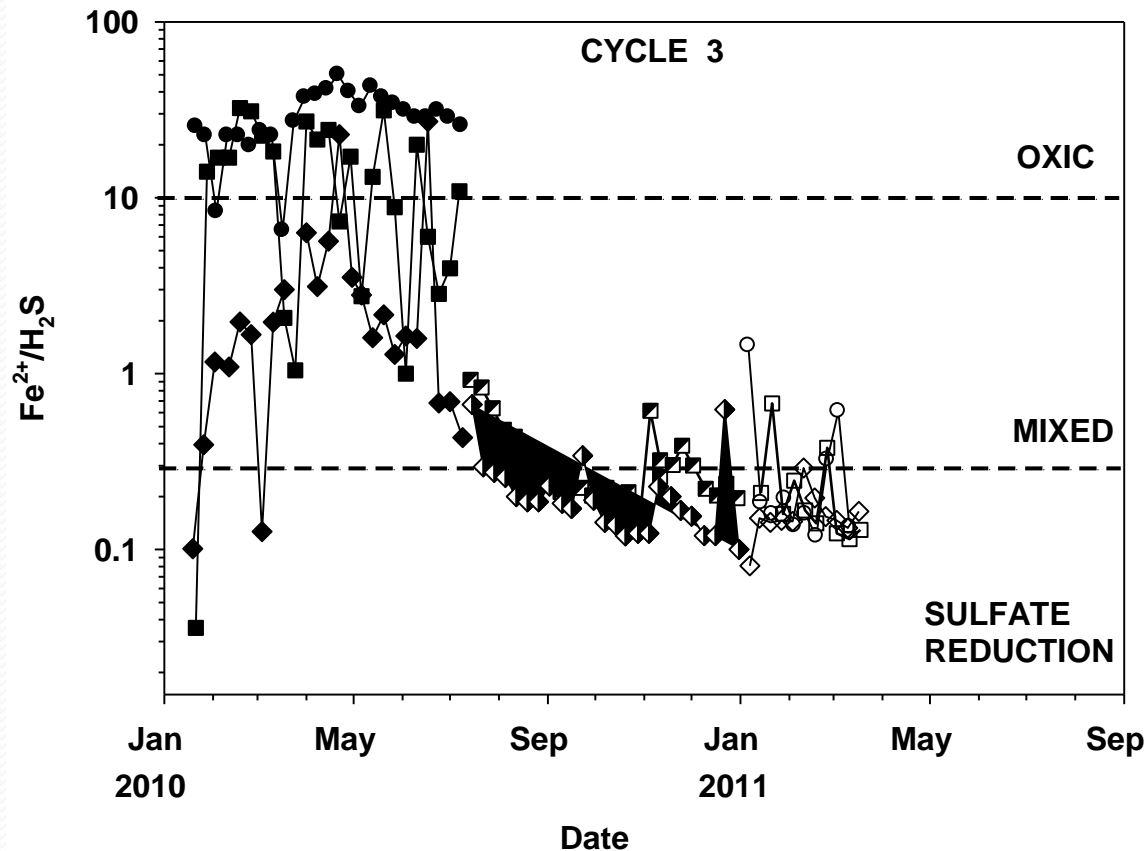
ASR Well	350-ft SZMW	1,100-ft SZMW
● Recharge	■ Recharge	◆ Recharge
○ Recovery	□ Storage	◇ Storage
	□ Recovery	◇ Recovery

Chapelle et al. (2009)
define criteria to
separate redox zones
using

$\text{Fe}^{2+}/\text{H}_2\text{S}$ ratio

Conclusion: ASR
wellfield evolves from
oxic to mixed ferric
iron/sulfate reducing to
sulfate reducing only
condition as the cycle
proceeds

Redox Evolution During ASR Cycle Testing

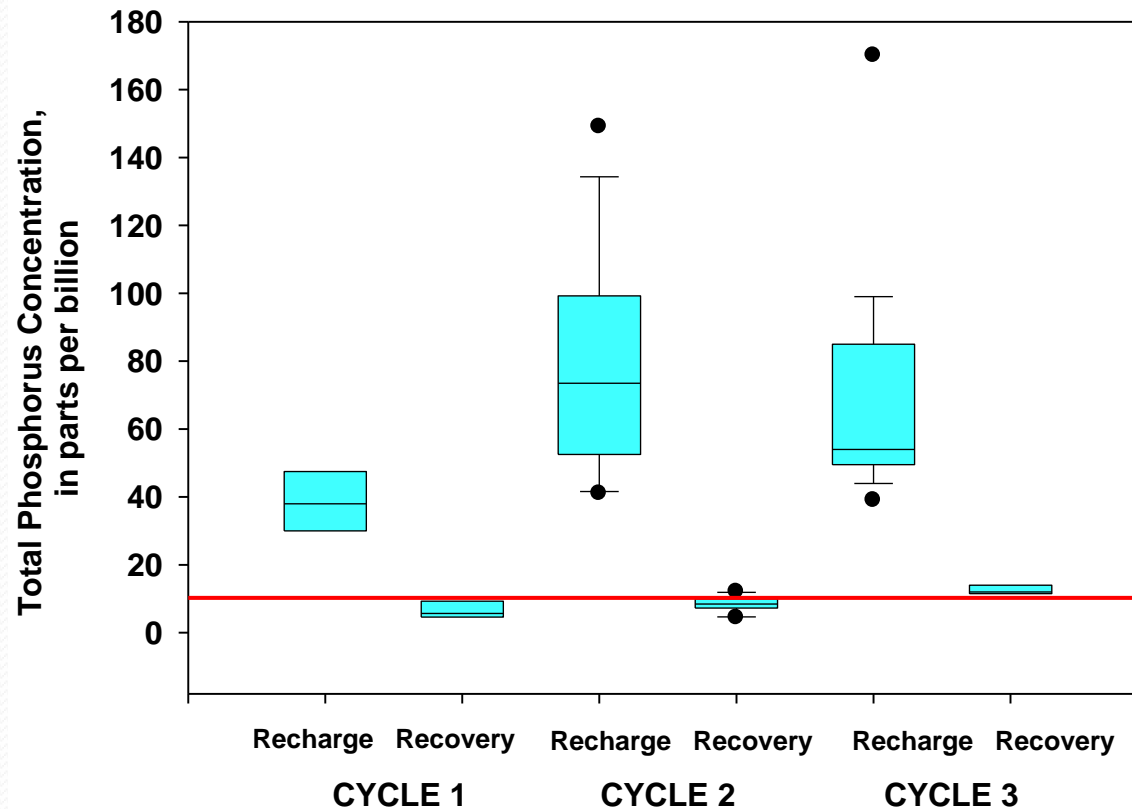


B.

Cycle 3 shows same trend

Aquifer evolves toward mixed ferric iron and sulfate redox conditions starting in recharge phase

Phosphorus Attenuation During ASR Cycle Testing



Kissimmee River ASR Pilot Site Status

- 3 Cycles completed (793 MG recharged/recovered)
- Cycle 4 recharge began 6 July 2011
Target 1 BG recharge/recovered, 1 yr storage
- Arsenic mobilization is temporary, and attenuates in the FAS *under these conditions*
 - high TOC, Fe recharge water
 - sulfate-reducing conditions in native FAS
- Cycles 2 and 3 recovered water all >10 ppb As
- Phosphorus attenuates to below 10 ppb
- Could this site get an operating permit?



ASR PDT in RECOVERY

Thanks very much to
Bob Verrastro, SFWMD
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AMEC – water quality
Mike Bennett and Paul Petrey,
Aqua Sulis