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Managing Aquifer Recharge: A Showcase for Resilience and Sustainability

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2021.03.22

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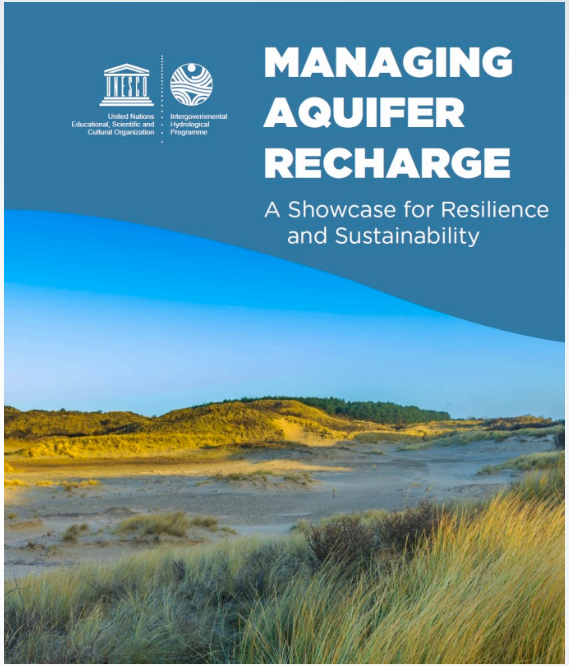

World Water Day 2021 Workshop on MAR in North America

Valuing Water

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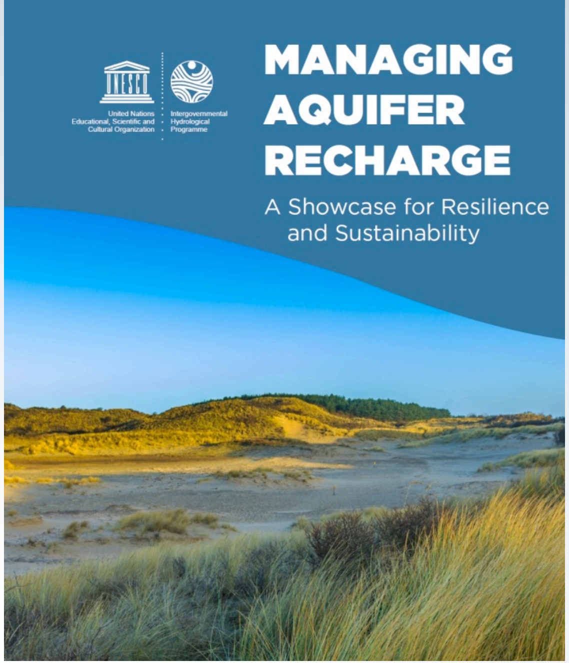

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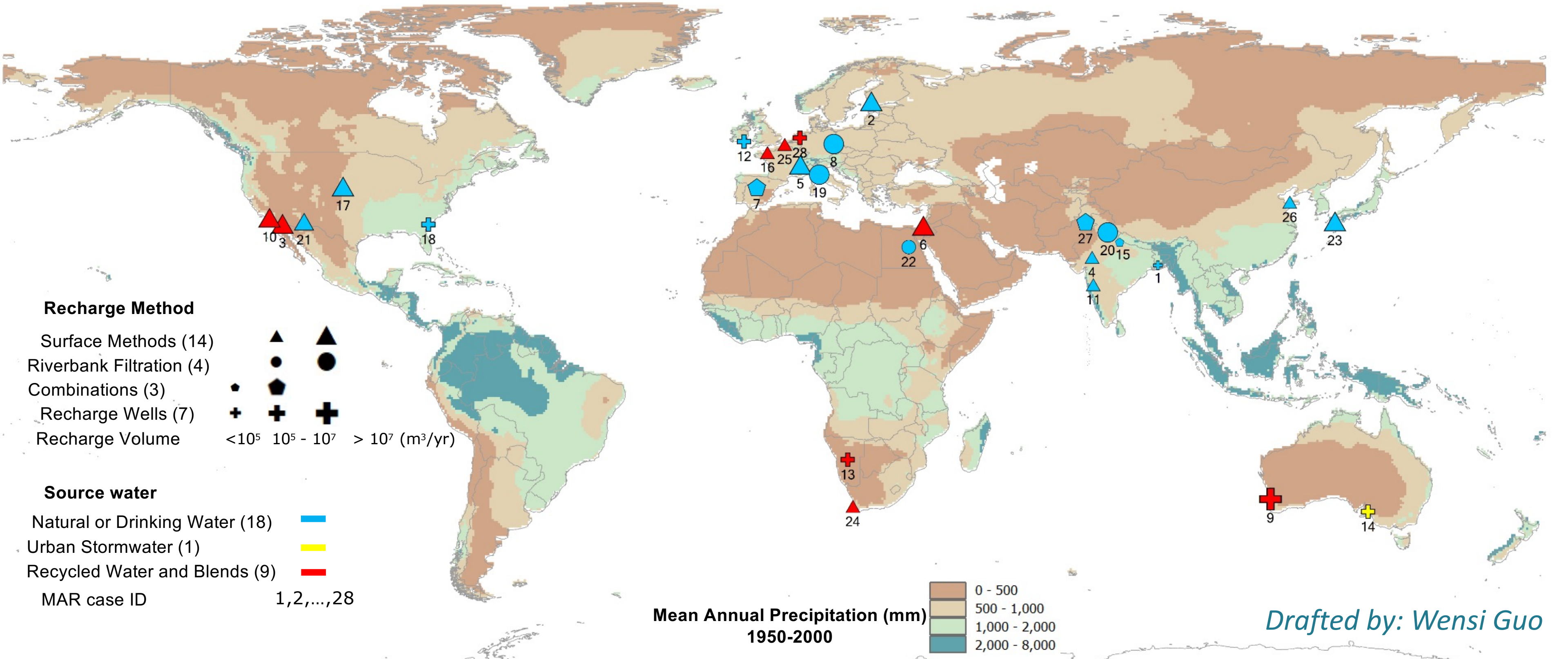
Locations of 28 MAR Schemes: Recharge methods and volume, source water types



Drafted by: Wensi Guo

Villholth, K.G. An Overview of Features of the MAR Case Studies. in Zheng, Y., Ross, A., Villholth, K and Dillon, P. (eds) (in press) Managing Aquifer Recharge: A Showcase for Resilience and Sustainability. UNESCO Publication

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17. Nebraska USA
West Pond
East Pond
25. Veurne Belgium
Filtration tank
Infiltration Well
1. Khulna, Bangladesh
10. Santa Ana River, California, USA
Surface Recharge Facilities
3. San Luis Río Colorado, Sonora, Mexico
18. Hilton Island USA
20. Haridwar India
NV
UT
CO
CA
Arizona
NM
Mexico
Central Arizona Project
Active Management Areas
Indian Communities
City Limits
Total AWBA Credits (AF)
10,000
50,000
100,000
500,000
21. Arizona USA
24. Atlantis S. Africa
Recharge Basin #12
9. Perth Australia
2
12
16
25
28
8
5
19
7
17
10
3
21
18
6
22
27
20
15
4
11
1
26
23
13
24
9
14
Source water
Natural or Drinking Water (18)
Urban Stormwater (1)
Recycled Water and Blends (9)

Lessons Learned

1. For the same purpose, cost of MAR schemes is usually less than half that of alternatives
2. Water quality challenges > water quantity challenges
3. Supportive regulatory systems enhance sustainability
4. Better energy intensity tracking is necessary for MAR opportunities arising from evolving water and wastewater treatment processes

According to IAH-MAR Commission (recharge.iah.org), managed aquifer recharge (MAR), also called groundwater replenishment, water banking and artificial recharge, is the ***purposeful recharge*** of water to aquifers for **subsequent recovery or environmental benefit.**

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Lesson 1

Cost and Cost-Benefit Analysis

Levelised Cost in 2016 US$:

- the constant level of revenue necessary each year to recover all the capital, operating and maintenance expenses over the life of the project divided by the annual volume of water supply
- When recovery volumes unavailable or purpose not for recovery then annual recharge volume is used
- operating life = 30 years, discount rate = 5.0%, are used for most schemes

Benefit:

- Diverse benefits (water supply for cities and agriculture, reserve supply, water quality improvement)
- If the main benefit of a MAR scheme is additional water supply:

1) Volume of water recovered or supplied multiplied by the cost of supply;
2) Alternative cost of production (used for most schemes)

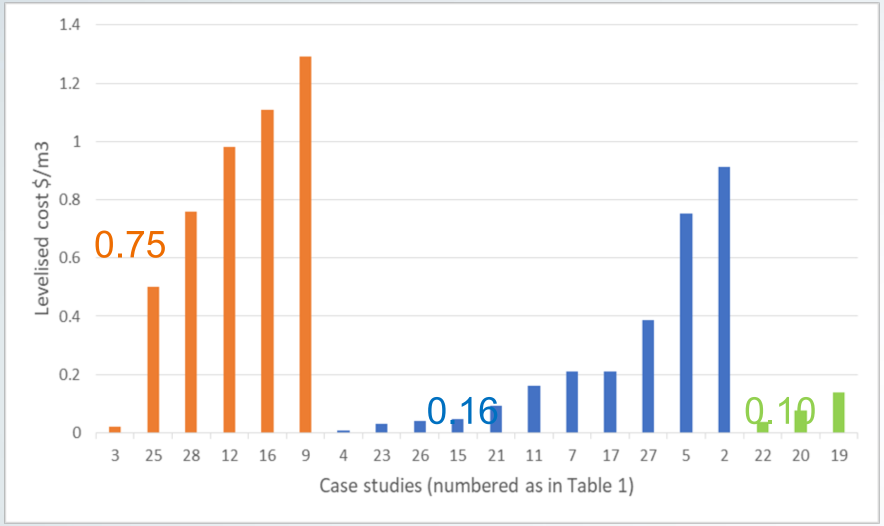
- Examples of other purposes:

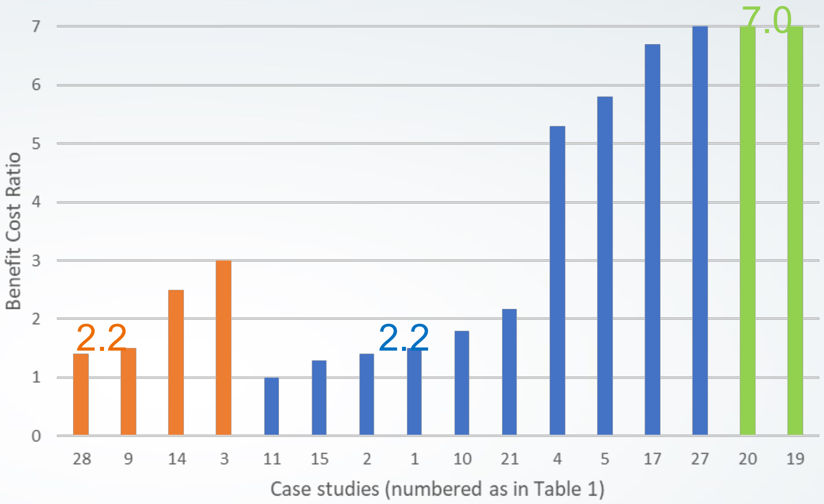
1) Net benefit from agricultural/industrial production
2) Costs of the next cheapest water treatment facility

Ross, A. Economic costs and benefits of managed aquifer recharge. in Zheng, Y., Ross, A., Villholth, K and Dillon, P. (eds) (in press) Managing Aquifer Recharge: A Showcase for Resilience and Sustainability. UNESCO Publication

Levelised costs (US$/m^3) Benefit : Cost ratios

Volume weighted							
Mean:	0.75	0.16	0.10	BCR	2.19	2.16	7
No of schemes:	6	11	3		4	10	2





recycled water schemes natural water schemes riverbank filtration schemes

Generally, MAR schemes achieved the same purpose at less than half the cost of alternatives.

To what extent is MAR Infrastructure an economical and sustainable water resource system?

Sustainable water resource systems are those designed and managed to fully contribute to the objective of society, *now and in the future*, while maintaining their ecological, environmental, and hydrological integrity.

Source: Loucks and Gladwell (ed.) 1999. Sustainability Criteria for Water Resources Systems, UNESCO-IHP Series, Cambridge University Press, pp 137

Wanted: Outstanding examples of sustainable and economic managed aquifer recharge

UNESCO-IAH-GRIPP book on Managed Aquifer Recharge planned in 2018

Lesson 2

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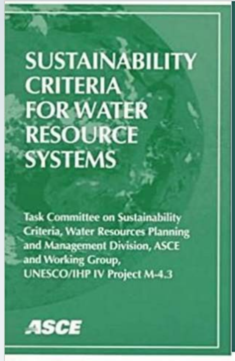
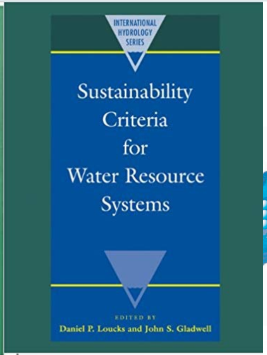
Sustainability Index:

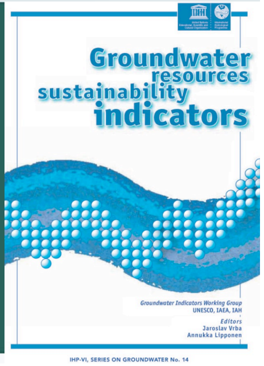
- Reliability
- Resilience
- Vulnerability

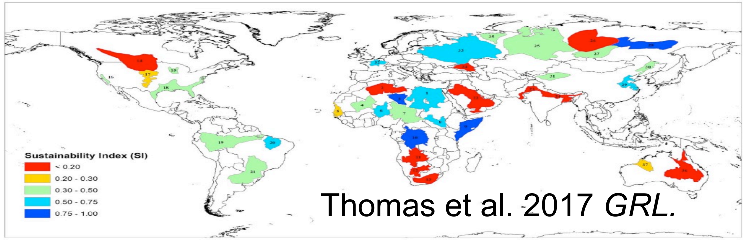
ENVISION by ASCE:

- Quality of Life
- Leadership
- Resource Allocation
- Natural World
- Climate and Risk









Thomas et al. 2017 *GRL.*

$$\text{sustainability index (SI)} = \text{REL} \times \text{RES} \times (1 - \text{VUL})$$

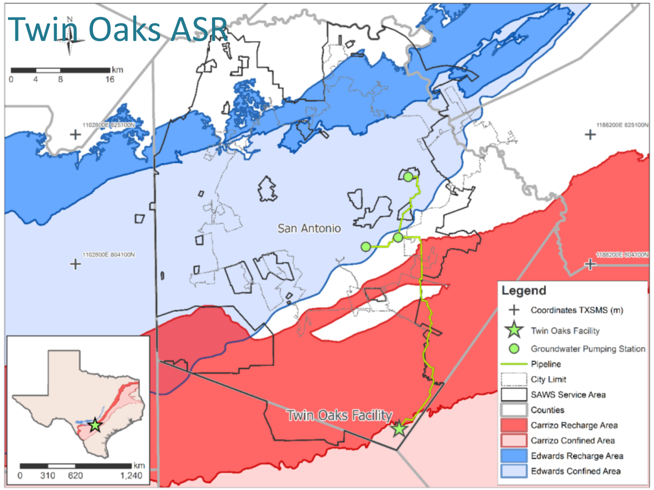


Figure 1. The Twin Oaks Facility in Bexar County, Texas. Data courtesy of SAWS, Texas Natural Resources Information System (TNRIS), Texas Parks and Wildlife Department (TPWD).

Saville et al 2016. *Sustainability*

Conclusion: A water specific sustainability index is needed in conjunction with Envision.

Methods to measure sustainability of water resource systems are inadequate.

To ensure resource integrity and security, groundwater quality and quantity both need protection.

US EPA Sustainability Criteria

Sustainability Criteria Below are the three pillars of sustainability, each with six broad topics that relate to its respective pillar. A brief explanation and example are provided for each topic. The examples are not intended to be inclusive.

Environmental

Ecosystem Services
Protect, sustain, and restore the health of critical natural habitats and ecosystems
Example: Innovative nutrient management techniques (Green Infrastructure)

Green Engineering & Chemistry
Design chemical products and processes to: eliminate toxic hazards, reuse or recycle chemicals, and reduce total lifecycle costs.
Example: Lifecycle Assessments in molecular design

Air Quality
Attain and maintain air-quality standards and reduce the risk from toxic air pollutants
Example: Investigate potential greenhouse gas emissions reduction strategies

Water Quality
Reduce exposure to contaminants in water systems and infrastructure (including protecting source waters), optimizing aging systems, and next generation treatment technologies & approaches.
Example: Purpose driven water reuse and innovative treatment technologies

Stressors
Reduce effects by stressors (e.g. pollutants, greenhouse gas emissions, genetically modified organisms) to the ecosystem and vulnerable populations
Example: Fate of modified nanoparticles in aqueous media

Resource Integrity
Reduce adverse effects by minimizing waste generation to prevent accidental release and future cleanup.
Example: Innovative technologies and processes to prevent environmental impact

Social

Environmental Justice
Protect health of communities over-burdened by pollution by empowering them to take action to improve their health and environment
Example: Establish partnerships with local, state, tribal, and Federal organizations to achieve healthy and sustainable communities

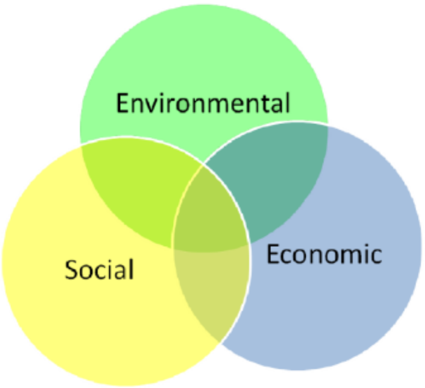
Human Health
Protect, sustain, and improve human health
Example: Parameterize model which predicts developmental toxicology

Participation
Use open and transparent processes that engage relevant stakeholders
Example: Develop database of reduced-risk pesticides for commonly used products, create greater public access and understanding about sustainability

Education
Enhance the education about sustainability of the general public, stakeholders, and potentially affected groups.
Example: Provide opportunities for students and communities to learn about sustainability

Resource Security
Protect, maintain, and restore access to basic resources (e.g. water, food, land, and energy) for current and future generations
Example: Study impact of dispersants/oil combination on natural waterways

Sustainable Communities
Promote the development, planning, building, or modification of communities to promote sustainable living
Example: Landscape with native plant species, green buildings



Economic

Jobs
Strengthen and maintain current and future jobs
Example: Promote jobs through introduction of innovative technologies and practices that provide multiple benefits to communities and the environment

Incentives
Promote incentives that work with human nature to encourage sustainable practices.
Example: Collaborative urban stormwater management approaches—Chesapeake Bay Partnership

Supply and Demand
Promote fully informed accounting and market practices to promote environmental health and social prosperity.
Example: Full lifecycle cost and benefit accounting techniques

Natural Resource Accounting
Improve understanding and quantification of ecosystem services in cost benefit analysis.
Example: Sustainability Assessments

Costs
Positively impact costs of processes, services, and products throughout the full lifecycle
Example: Strive to develop waste-free processes—eliminating need for regulation, treatment, and disposal costs throughout systems

Prices
Promote cost structures that reduce risk and premium for new technologies.
Example: Speed innovative technologies and approaches to the market

MAR sustainability indicators (from Zheng *et al* in press)

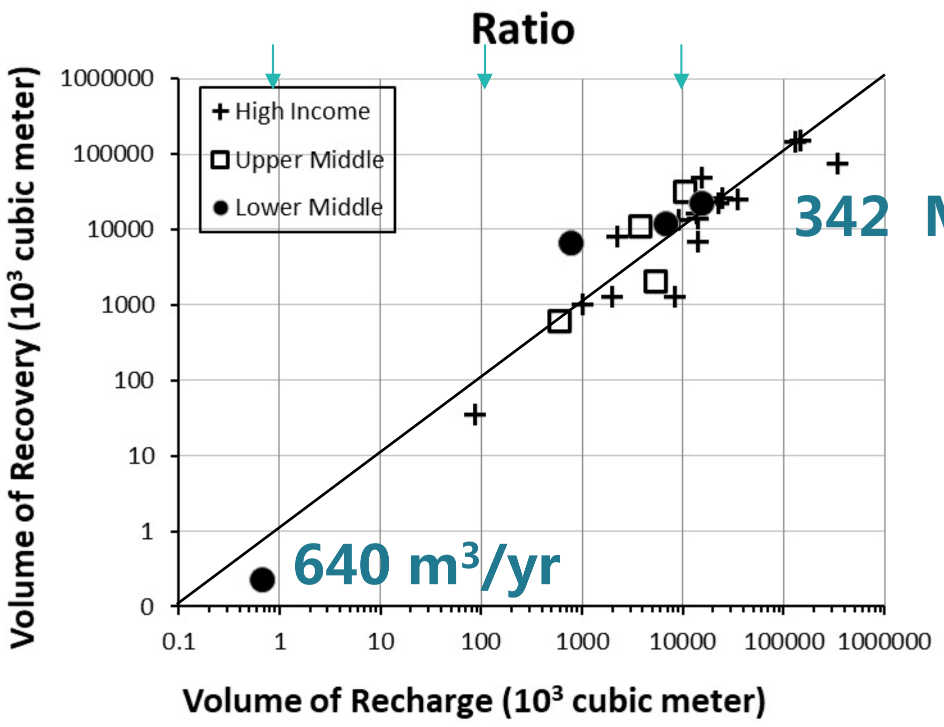
	Attribute	Indicator
ENVIRONMENTAL INDICATORS	Water quantity	1. Monitoring of groundwater table demonstrates acceptable changes over 10 years, or > 3 years with high likelihood of maintaining resource integrity 2. The ratio of volume of recovered water vs infiltrated water on an annual basis
	Water quality	3. Exceedance rate based on time-series monitoring of recovered or ambient water quality parameters 4. Exceedance rate based on time-series monitoring of source water quality parameters
	Ecosystem services	5. Changes in ecological flow (m/yr) and improvement in water quality in eco-system needing protection identified in a catchment water management plan
	Stressors	6. Energy requirements in KWh per cubic meter of recovered water, including monitoring and treating recovered water, solving clogging and low recovery efficiency issues
SOCIAL INDICATORS	Resource security	7. Clearly defined, transparent regulatory framework for MAR, preferably one that requires monitoring of resource integrity
	Human health	8. Permit granting process is based on sound risk assessment aimed to protect human health
	Community participation/ justice	9. Systematic Institutional arrangements for public and stakeholder consultation, preferably with regular publicly available reports of scheme outcomes

Zheng, Y. et al. An Assessment of Environmental and Social Sustainability for Managed Aquifer Recharge Schemes. in Zheng, Y., Ross, A., Villholth, K and Dillon, P. (eds) (in press) Managing Aquifer Recharge: A Showcase for Resilience and Sustainability. UNESCO Publication

Lesson 2

Annual Recharge Volume

Micro: <10^3 Small: 10^3 - 10^5 Medium: 10^5 - 10^7 Large: > 10^7 (m^3/yr)



1 m^3

35.3 ft^3

264 gallon

$V_{recovered}/V_{recharged}$ (n=26)

- Range: 0.0-8.3
- Mean: 1.4 ± 1.7

Induced Bank Filtration (n=3):

- 1.1, 1.2, 1.4

$V_{recovered}/V_{recharged}$>2 (n=4)

- London UK for drought: 3.2
- Sergovia Spain for drought: 3.6
- Windhoek Namibia for drought: 2.9
- Rajasthan India for drought: 8.3

Indicator 2. Resource Integrity – Water Quantity
The ratio of volume of recovered water vs infiltrated water on an annual basis

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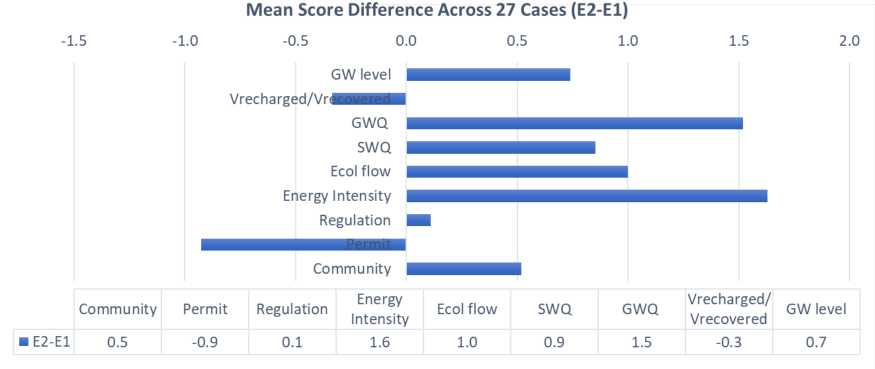
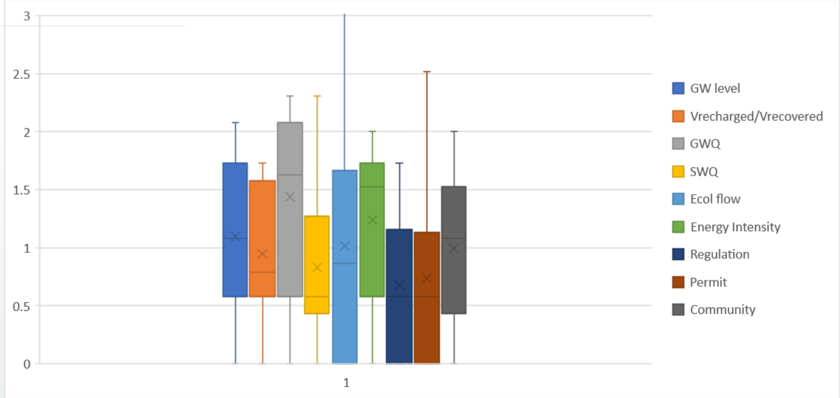
Higher Income -> Higher Sustainability Rating

Table 5. Sustainability Rating of MAR Cases

Country	Location	Rating by Two Experts	Indicator[1]: Expert Mean [2]	1 GW level	2 $V_{recharged}/V_{recovered}$	3 GWQ	4 SWQ	5 Ecol flow	6 Kwh/m^3	7 Regu-lation	8 Per-mit	9 Commu nity
High Income: > 12,375		**2: Enhanced**		S E1 E2	S E1 E2	S E1 E2	S E1 E2	S E1 E2	S E1 E2	S E1 E2	S E1 E2	S E1 E2
Mean High Income (n=17)			***1.9***	***2.5***	***2.4***	***1.2***	***0.5***	***1.1***	***1.0***	***3.0***	***2.6***	***2.4***
Upper Middle: 3,996 - 12,375												
Mean Upper Middle (n=4)			***1.3***	***2.1***	***2.3***	***-0.1***	***-0.3***	***1.3***	***1.0***	***2.1***	***2.1***	***1.0***
Lower Middle: 1,026 - 3,995		**1: Improved**										
Mean Lower Middle (n=7)			***0.7***	***0.8***	***1.7***	***0.3***	***0.4***	***-0.2***	***1.3***	***0.4***	***0.6***	***1.5***
Min				0.0	0.0	-3.0	-1.0	-3.0	-3.0	-1.0	0.0	0.0
Max				5.0	5.0	5.0	4.0	5.0	4.0	5.0	5.0	5.0
Mean of all schemes				**2.1**	**2.2**	**0.8**	**0.4**	**0.8**	**1.1**	**2.3**	**2.1**	**2.0**

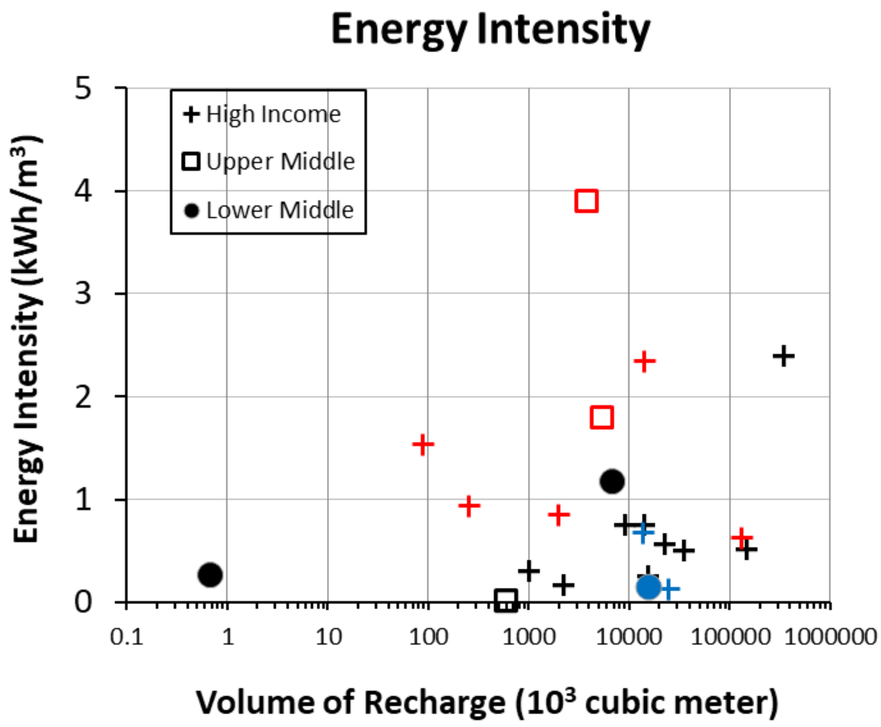
0: No Value Added





Lesson 4

Consider and track energy intensity in design and implementation



Energy Intensity (n=23) kWh/m³

- Range: 0.02-3.9
- Mean: 0.9 ± 0.9

Induced Bank Filtration (n=4)

- 0.13, 0.68, 0.30, 0.16

Effluent as Source Water (n=7)

- 1.7 ± 1.1

Indicator 6 - Stressor.
Energy requirements in KWh per cubic meter of recovered water, including monitoring and treating recovered water, solving clogging and low recovery efficiency issues

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Summary and Conclusions

1. This documentation of evolution of **exemplary schemes**, together with the applied **toolkit of sustainability assessment and economic analysis** are rich resources for water managers considering MAR and for stakeholders of MAR projects to enhance climate resilience and other social, economic and environmental benefits of their projects.

2. Schemes from higher income countries received **better sustainability ratings primarily due to supportive regulatory systems.** Strengthening institutional capacity for regulatory frameworks for water allocation, permit granting and water quality protection are especially relevant for developing countries and localities challenged by climate change.

3. **Water quality challenges** are typically greater than water quantity challenges for maintaining resource integrity. **Ecological flow/**ecosystem and social objectives are often secondary to other objectives and deserve more attention by MAR promoters. **Energy intensity** while important is often poorly tracked. **Community engagement** also warrants greater attention.

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Acknowledgement

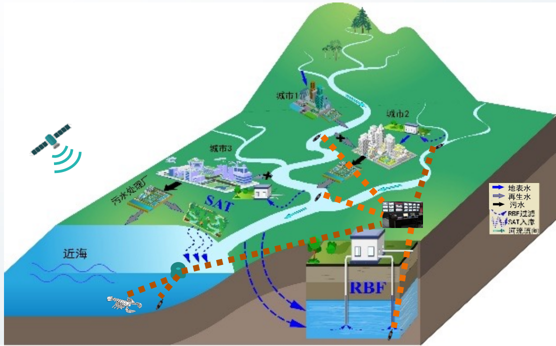
- Authors of 28 case studies
- Organizations that initiated and operated these MAR schemes
- UNESCO-IHP, IAH-MAR Commission, GRIPP
- DANIDA Fellowship MAR-in-China

UNESCO IHP-VIII WATER SECURITY (2014-2021)

Theme (2) **“Groundwater in a Changing Environment”**
In order to **incorporate MAR to Integrated Water Resource Management**, the Focal Area “Addressing strategies for management of aquifer recharge” will

- develop and apply **methods** to assess the impact of MAR schemes on water availability and quality, social and economic resilience and local ecosystems;
- evaluate the **risks and benefits** of recycling appropriately treated wastewater and storm water for safe irrigation or drinking water supplies;
- enhance **governance** capacities, and institutional and legal frameworks to aid effective implementation.

Protecting groundwater resources is vital for achieving Sustainable Development Goals.



Do the Indicators work?

Table 2. Levels of Achievement in Envision with Modification for Sustainability Rating of Cases in this Study					
ASCE Envision [2] 60 sustainability criteria in 5 categories			This Study 9 sustainability indicators in 5 categories of USEPA		
Level (+)	Performance Definition	Points for Rating*	Level (-)	Performance Definition	Points for Rating
No added value	comparable to conventional	0			
Improved	is at or above conventional	1	Degraded	is below conventional alternative	-1
Enhanced	Indications that superior performance is within reach	2	Diminished	Indications that there are risks for inferior performance	-2
Superior	noteworthy	3	Inferior	obvious poor performance	-3
Conserving	has achieved essentially zero impact	4	Harming	harmful impact in one aspect	-4
Restorative	restores natural or social system	5	Debilitating	harmful impact in all aspects	-5

*In Envision, the points possible is variable for each criterion, for example, "conserving" for "Protect fresh water availability" under category Resource Allocation (total points possible is 182) can earn up to 21 points

To simplify, this study assigns positive or negative points at a step value of 1

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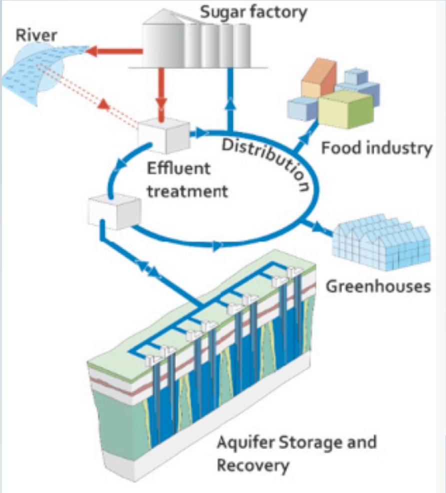


Lessons Learned and Implications

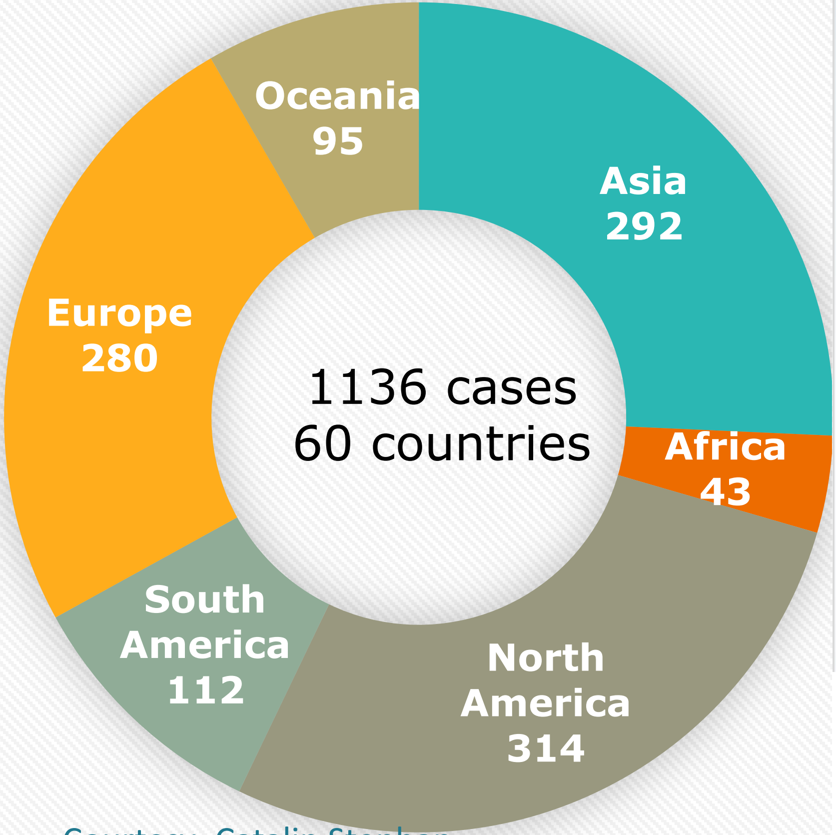
MAR
Technique:

ASR
Aquifer-
Storage=
Recovery

28. Zuurbier et al., Dinteloord, the Netherlands

1. Ahmed et al., Kulna, Bangladesh

Global MAR Inventory



Courtesy: Catalin Stephan

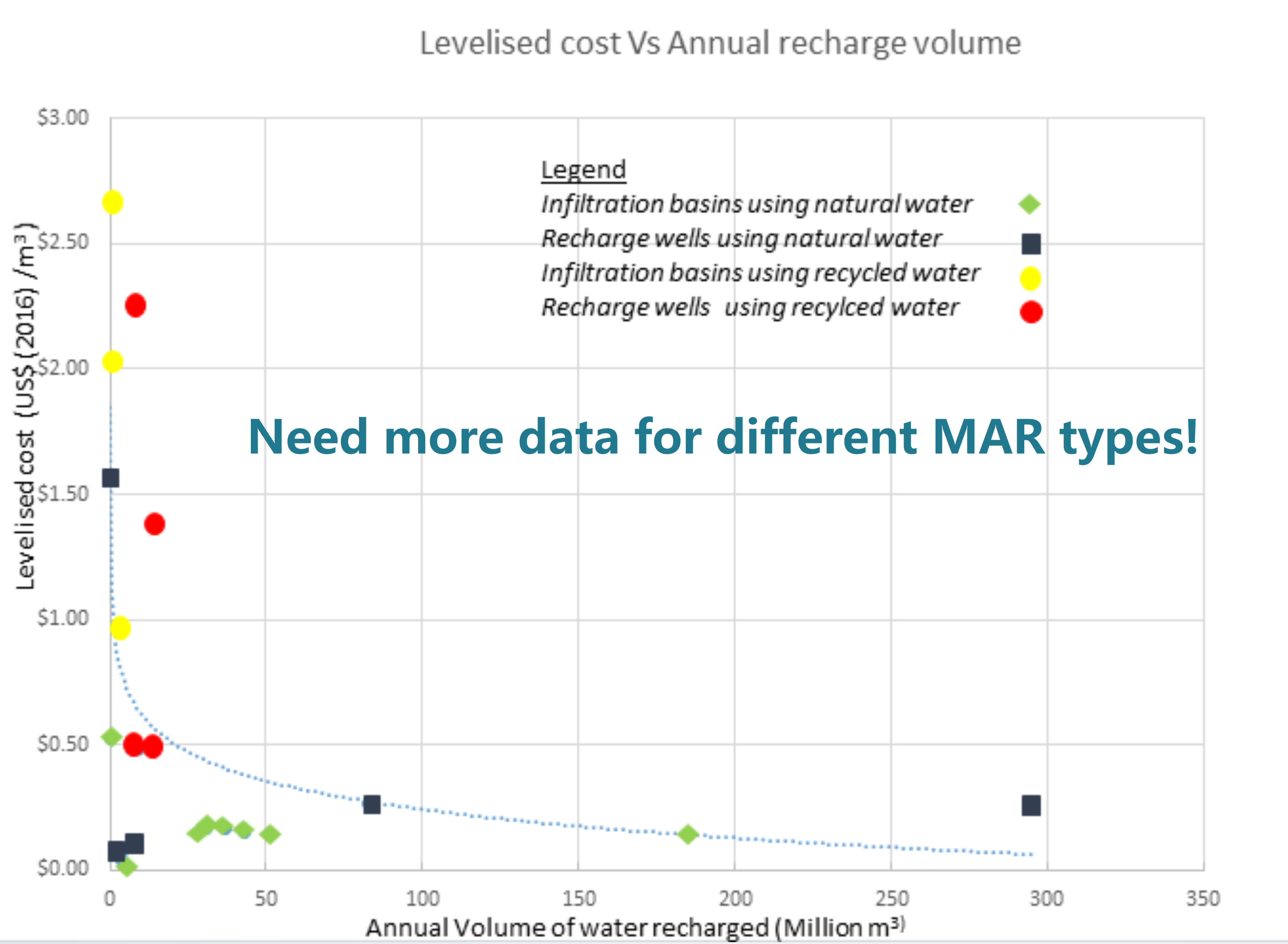
Quantity (km^3/yr)

	Groundwater Use in 2010	MAR Quantity in 2015	%MAR of GW Use
Global	982	9.9	1.0%
USA	112	2.5	2.3%
Australia	4.96	0.41	8.3%
China	112	0.106	0.1%
India (5 states)	39.8	3.07	7.7%
Denmark	0.65	0.00025	0.0004%
Finland	0.28	0.065	23.2%

Sixty years of global progress in managed aquifer recharge

Hydrogeology Journal (2019) 27:1–30

P. Dillon[1,2] · P. Stuyfzand[3,4] · T. Grischek[5] · M. Lluria[6] · R. D. G. Pyne[7] · R. C. Jain[8] · J. Bear[9] · J. Schwarz[10] · W. Wang[11]
E. Fernandez[12] · C. Stefan[13] · M. Pettenati[14] · J. van der Gun[15] · C. Sprenger[16] · G. Massmann[17] · B. R. Scanlon[18] ·
J. Xanke[19] · P. Jokela[20] · Y. Zheng[21] · R. Rossetto[22] · M. Shamrukh[23] · P. Pavelic[24] · E. Murray[25] · A. Ross[26] ·
J. P. Bonilla Valverde[27] · A. Palma Nava[28] · N. Ansems[29] · K. Posavec[30] · K. Ha[31] · R. Martin[32] · M. Sapiano[33]



Need more data for different MAR types!

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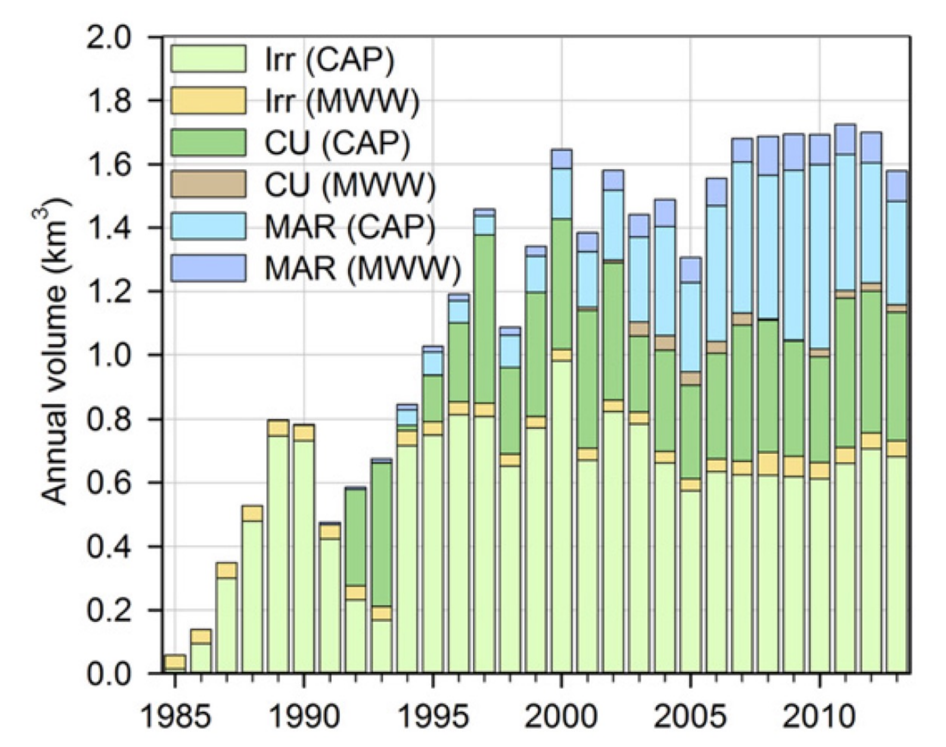
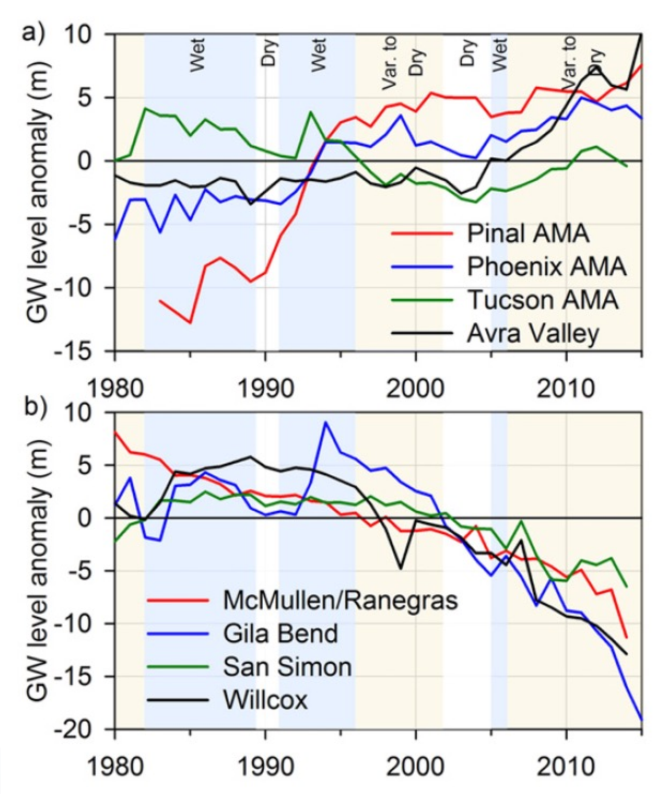
Indicator 1 - Resource Integrity
Monitoring of groundwater table demonstrates acceptable changes over 10 years





Scanlon et al. Enhancing drought resilience with conjunctive use and managed aquifer recharge in California and Arizona. *Env Res Lett* 11 (2016)035013

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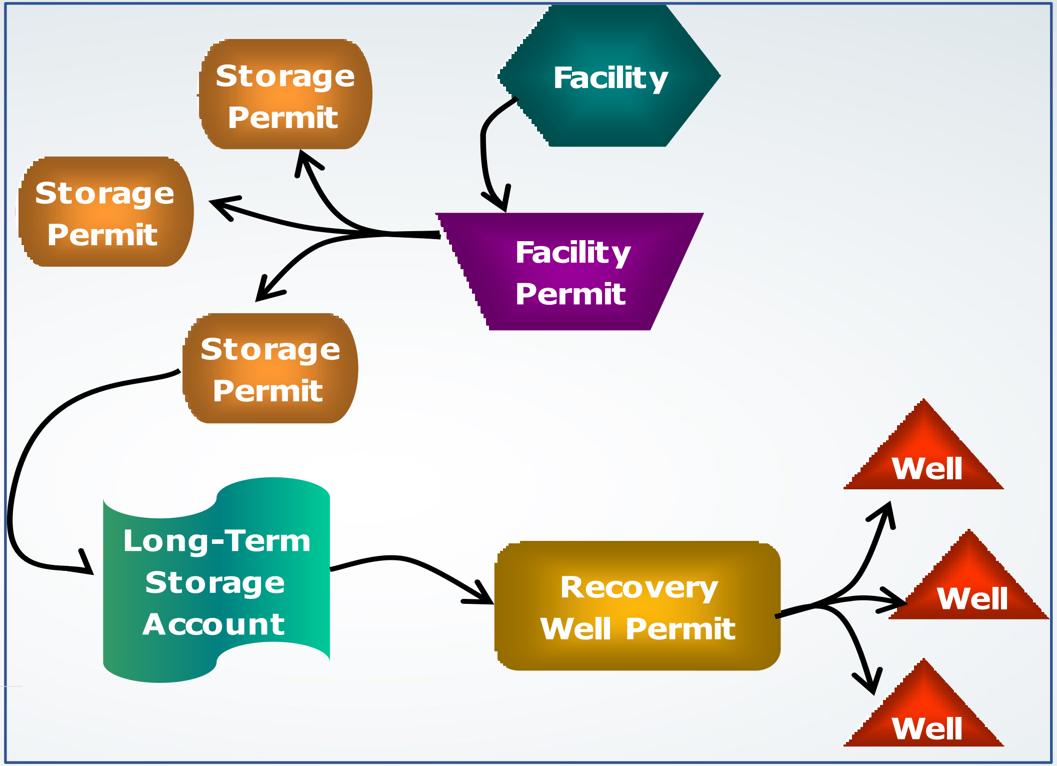
Arizona Showcase: Credits Crucial for Water Banking

Since the establishment of the **Arizona Water Banking Authority (AWBA)** in 1996, nearly 5,600 million cubic meter (MCM) of Colorado River water has been stored.

A flexible, mass-balance approach to MAR accounting:

- the future right to recover (i.e., pump) 95% of the volume that was stored;
- the ability to recover almost anywhere within the regional aquifer system;
- the ability of the recovered water to retain the legal character of the stored water.

After detailed calculation of losses, ADWR issues **Long-Term Storage Credits**



Seasholes, K. and Megdal, S. (2020) The Arizona Water Banking Authority: The Role of Institutions in Supporting Managed Aquifer Recharge. Case study 21 in Zheng et al (eds). Managing Aquifer Recharge: A Showcase for Resilience and Sustainability . UNESCO Publication, in press.

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10 Environmental Sustainability Indicators for MAR

A. Resource Integrity

A.1 Water Quantity

1. Monitoring of groundwater table demonstrates acceptable changes over 10 years, or > 3 years with high likelihood of maintaining resource integrity
2. The ratio of volume of infiltrated water vs recovered water on an annual basis
3. For large schemes, change in renewable groundwater resources in target aquifer per capita (m^3/year per capita)

A.2 Water Quality

4. Exceedance rate based on time-series monitoring of recovered or ambient water quality parameters
5. Exceedance rate based on time-series monitoring of source water quality parameters
6. For large MAR schemes, percentage use as drinking water sourced from target aquifer

B. Ecosystem Services

7. Change in ecological flow (m^3/yr) in ecosystems needing protection identified in a catchment water management plan
8. Change in peak flow (m^3/s) for MAR intended for flooding control

C. Stressors

9. Energy requirements to monitor and treat recovered water, solve clogging and low recovery efficiency issues are not excessive
10. No unacceptable seepage, waterlogging, discharge occurs

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4 Social Sustainability Indicators for MAR

D. Resource Security/Human Health

11. Clearly defined, transparent regulatory framework for MAR, preferably one that requires monitoring of resource integrity
12. Permit granting process is based on sound risk assessment aimed to protect human health
13. Assists resilience to adverse impacts of climate change

E. Sustainable Community/Participation/Education/Environmental Justice

14. Systematic Institutional arrangements for public and stakeholder consultation, preferably with regular publicly available reports of scheme outcomes

Please provide your feedback on the 14 indicators proposed for MAR

score with the following scale:

Do not include 0

OK to include 4

Good to include 7

Must include 10

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Orange County Groundwater Basin Managed Aquifer Recharge Program for Santa Ana River Flow

Adam Hutchinson, OCWD
Greg Woodside, OCWD

UNESCO World Water Day Special Webinar
March 22, 2021

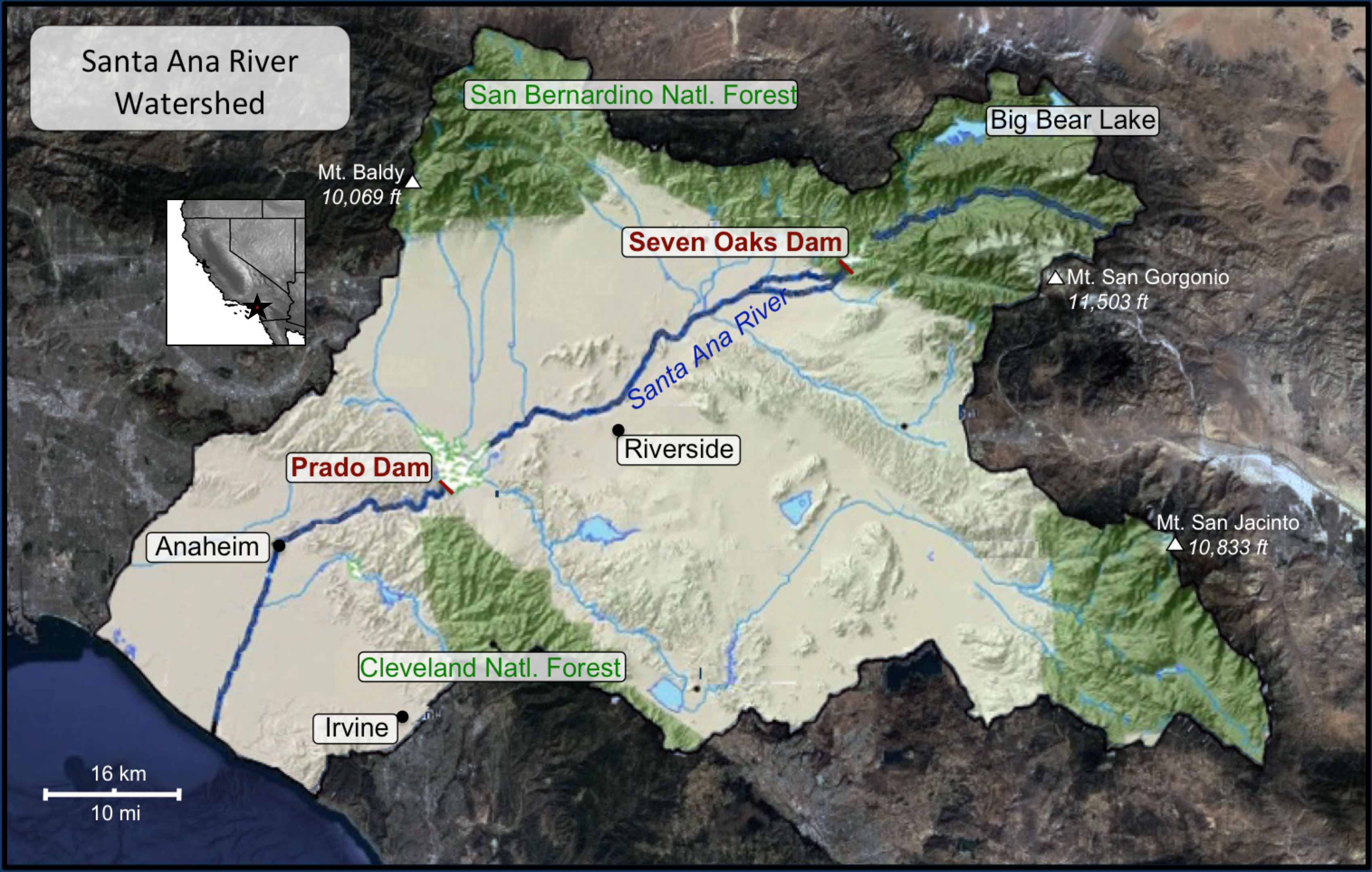
The Orange County Water District was formed by the State in 1933 to protect and manage Orange County's groundwater supplies.

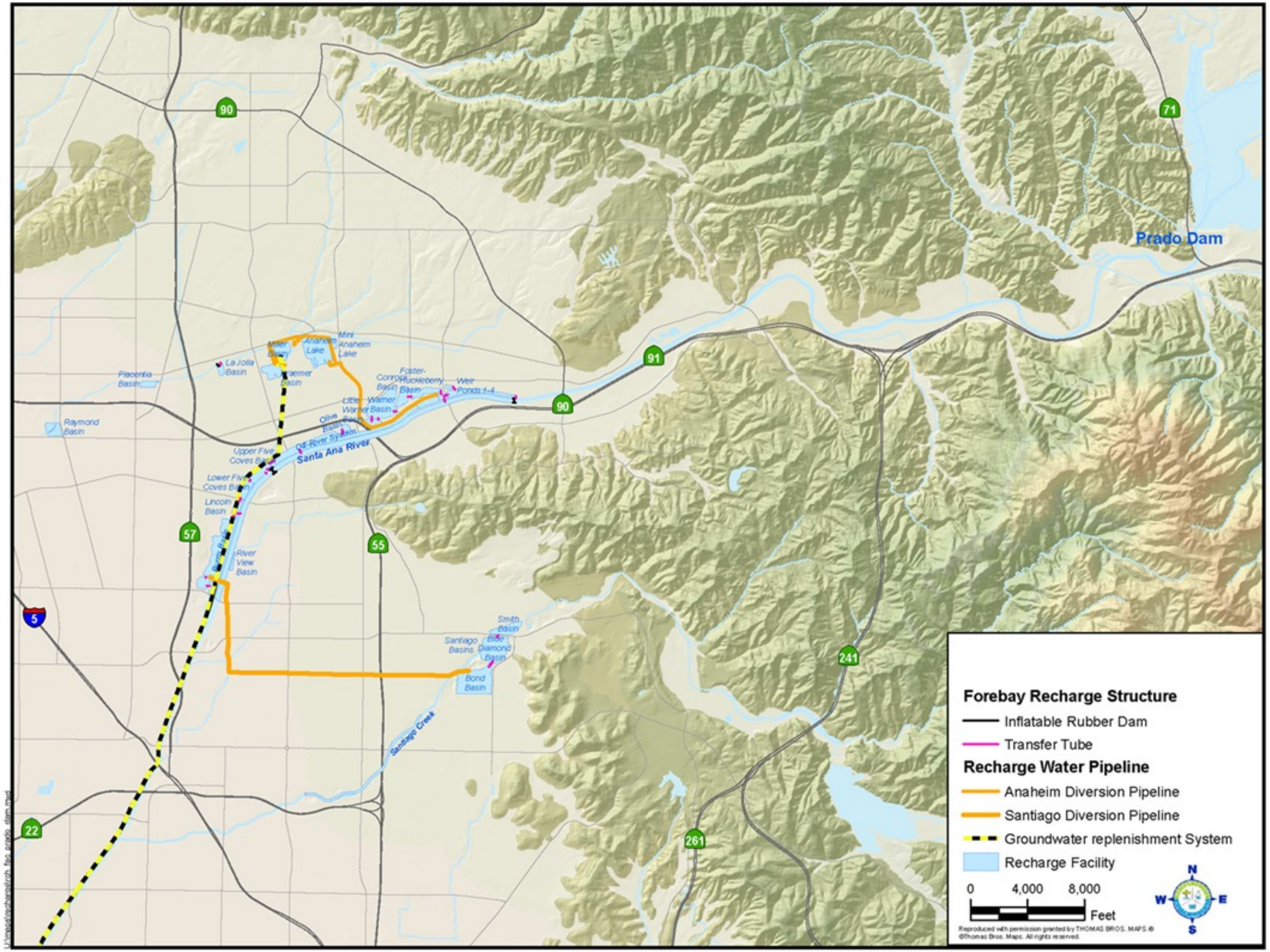
Why?

- Declining flow of Santa Ana River
- Basin overdraft
- Seawater intrusion

Provides groundwater

- 19 municipal and special water districts
- 2.5 million customers in north & central OC

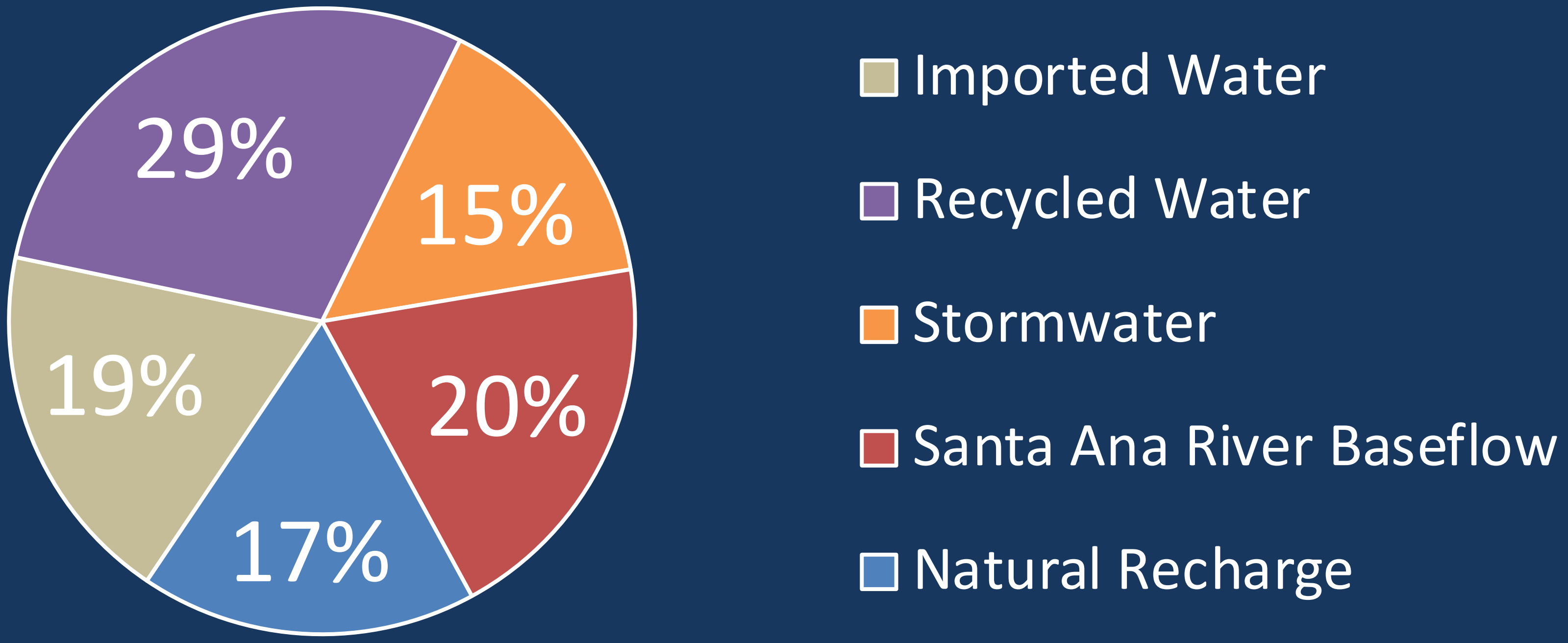

Santa Ana River Watershed
San Bernardino Natl. Forest
Big Bear Lake
Mt. Baldy
10,069 ft
Seven Oaks Dam
Mt. San Gorgonio
11,503 ft
Santa Ana River
Riverside
Prado Dam
Anaheim
Mt. San Jacinto
10,833 ft
Cleveland Natl. Forest
Irvine
16 km
10 mi



OCWD has constructed a large recharge system approximately 18 km downstream of Prado Dam.

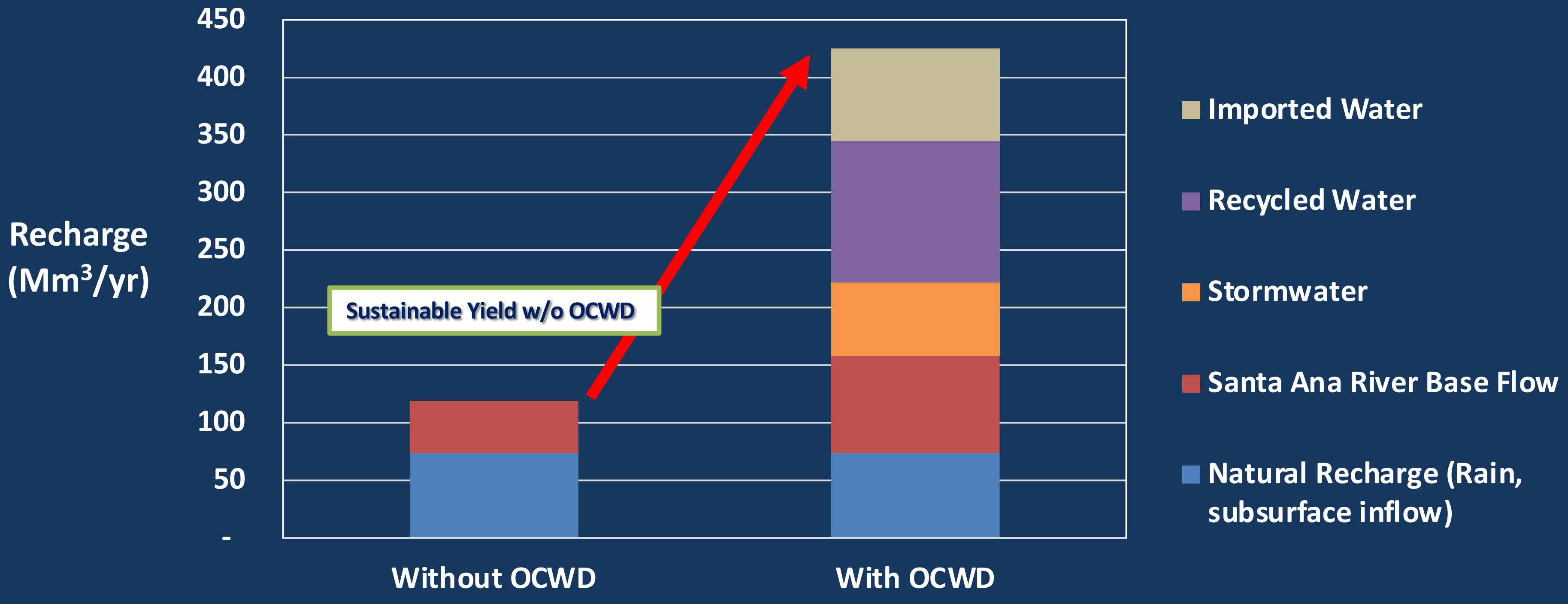
Up to 25 Mm^3 of stormwater can be temporarily captured at Prado Dam.

Multiple sources are used to refill the basin.

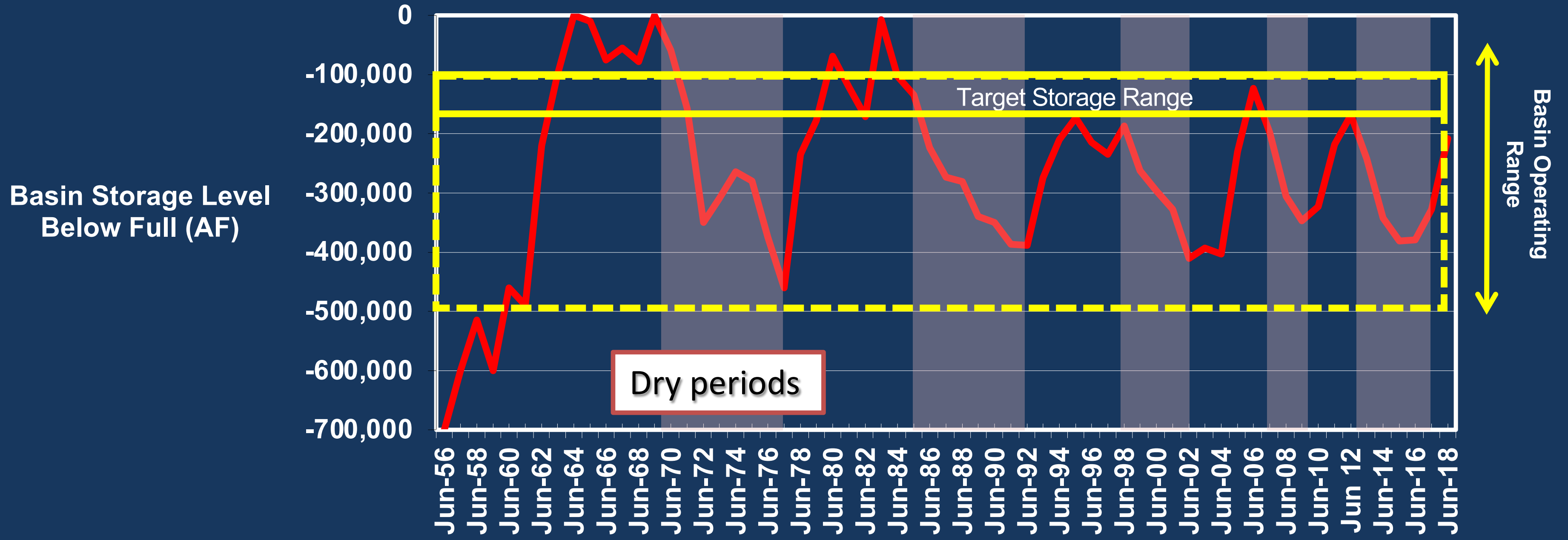


Average annual recharge:
425 Mm^3/yr (345,000 AFY, 115 billion gallons)

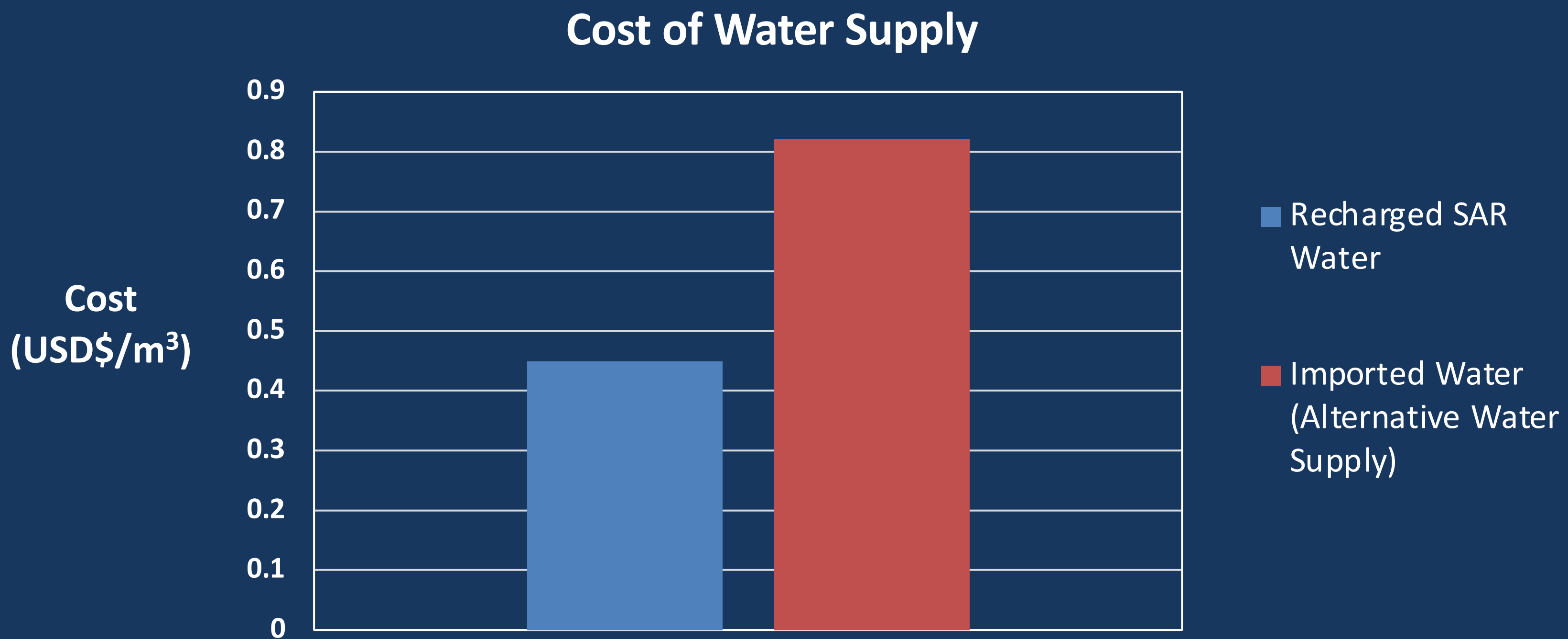
OCWD's Managed Aquifer Recharge system has more than doubled the yield of the basin.



Annual basin recharge/pumping is balanced based on average hydrology. Storage rises and falls based on wet/dry conditions.



Recharged SAR water is approximately ½ the cost of imported water (alternative supply).



OOMAPAS San Luis Río Colorado | UN Water 22 March World Water Day 2021 Valuing Water | College of Agriculture & Life Sciences Cooperative Extension Water Resources Research Center | International Association of Hydrogeologists the World-wide Groundwater Organisation | LATINMAR | Instituto de Ingeniería UNAM

World Water Day Special Webinar

Managing Aquifer Recharge: A Showcase for Resilience and Sustainability

"Managed Aquifer Recharge to Recycle Water for Agricultural Use in San Luis Río Colorado, Sonora, Mexico"

Raúl Campuzano, Humberto Hernández, Adriana Palma, Jorge Ramírez

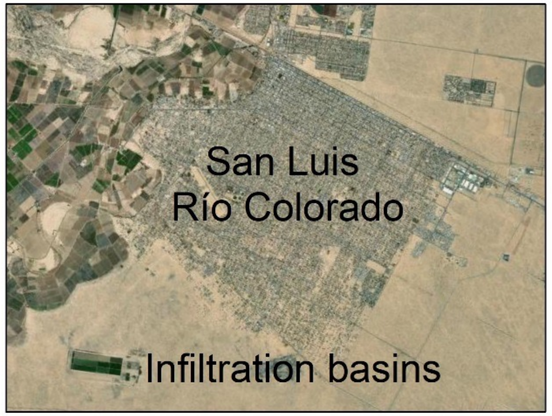
March 22, 2021

INTRODUCTION

San Luis Río Colorado (SLRC) city with 230,000 inhabitants is located in the Sonoran desert on the border of the Colorado river delta with a very low annual precipitation of 84 mm average.

The water availability is related to two main sources; groundwater of SLRC aquifer and surface water delivered by USA because of the International agreement between Mexico and USA to share water from transboundary basins.

This MAR project was the first of its kind in Mexico and it has served as a benchmark to carry out others MAR projects, and to develop MAR regulations.



Source: Humberto Hernández & Raúl Campuzano, OOMAPAS,SLRC.

TIMELINE

Non treatment

2005

PTAR operation

2005

Reuse opportunities

2005

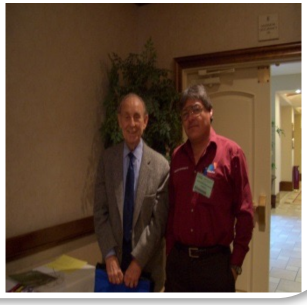
Advisory: P. Dillon

2006

MAR Project pilot

2006

Advisory: H. Bouwer

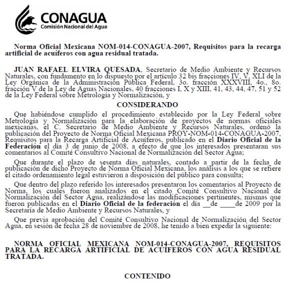


2007

MAR Project

2008

Mexican MAR regulation



CONAGUA
Comisión Nacional del Agua

Norma Oficial Mexicana NOM-014-CONAGUA-2007, Requisitos para la recarga artificial de acuíferos con agua residual tratada.

JUAN RAFAEL ELVIRA QUESADA, Secretario de Medio Ambiente y Recursos Naturales, con fundamento en lo dispuesto por el artículo 32 bis fracciones IV, V, XLI de la Ley Orgánica de la Administración Pública Federal, 3o. fracción XXXVIII, 4o., 8o. fracción V de la Ley de Aguas Nacionales, 40 fracciones I, X y XIII, 41, 43, 44, 47, 51 y 52 de la Ley Federal sobre Metrología y Normalización, y

CONSIDERANDO

Que habiéndose cumplido el procedimiento establecido por la Ley Federal sobre Metrología y Normalización para la elaboración de proyectos de normas oficiales mexicanas, el C. Secretario de Medio Ambiente y Recursos Naturales, ordenó la publicación del Proyecto de Norma Oficial Mexicana PROY-NOM-014-CONAGUA-2007, Requisitos para la Recarga Artificial de Acuíferos, publicado en el **Diario Oficial de la Federación** el día 3 de junio de 2008, a efecto de que los interesados presentaran sus comentarios al Comité Consultivo Nacional de Normalización del Sector Agua;

Que durante el plazo de sesenta días naturales, contado a partir de la fecha de publicación de dicho Proyecto de Norma Oficial Mexicana, los análisis a los que se refiere el citado ordenamiento legal estuvieron a disposición del público para consulta;

Que dentro del plazo referido los interesados presentaron los comentarios al Proyecto de Norma, los cuales fueron analizados en el citado Comité Consultivo Nacional de Normalización del Sector Agua, realizándose las modificaciones pertinentes, mismas que fueron publicadas en el **Diario Oficial de la federación** el día __de ____de 2009 por la Secretaría de Medio Ambiente y Recursos Naturales, y

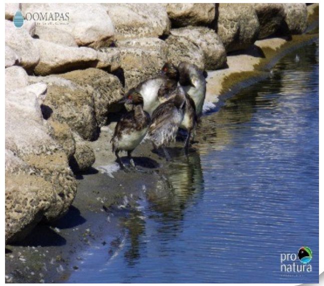
Que previa aprobación del Comité Consultivo Nacional de Normalización del Sector Agua, en sesión de fecha 28 de noviembre de 2008, he tenido a bien expedir la siguiente:

NORMA OFICIAL MEXICANA NOM-014-CONAGUA-2007, REQUISITOS PARA LA RECARGA ARTIFICIAL DE ACUÍFEROS CON AGUA RESIDUAL TRATADA.

CONTENIDO

2015

PRONATURA, birds habitat



2018

Cucapá Wetland

WASTE WATER TREATMENT PLANT

The treatment system is of the Biological-Lagunar type and has an installed capacity to treat a flow of 600 liters per second

The discharge of the WWTP is governed under NOM-001-SEMARNAT-1996

Area: 85.6 Ha

Capacity: 600 lps (9,511 gpm)

Source: Humberto Hernández & Raúl Campuzano, OOMAPAS,SLRC.

REUSE OPORTUNITY

The utility (OOMAPAS), base on the quality standards expected as a result of this treatment (NOM-001-ECOL-1996), sought the marketing of these waters for use in regional agriculture.

However, the cost of treatment per m^3, — despite being one of the cheapest in the world — significantly exceeded the cost per m^3 of water for agricultural irrigation.

Water irrigation district \$0.08/m^3

vs

Treated water \$0.86/m^3

Alternative options for the reuse of this resource:

- Send the water back to the Colorado River;
- Send the water to an irrigation channel called "Canal Independencia"
- Both options were 14 km from the starting point of the WWTP with an approximate construction cost of \$40,000,000 (2.85 millions USD).

Source: Humberto Hernández & Raúl Campuzano, OOMAPAS,SLRC.

MAR PROJECT PILOT

Saturated Hydraulic Conductivity
Kv = 4.8 m/day

Average Transmissivity = 2,246 m^2/day

Porosity = 25%

Storage Coefficient = 25%

Activities included:

- The development of maps containing the geographic location of the of recharge zone;
- Surrounding underground deposits;
- Potential sources of groundwater pollution;
- Satellite imagery showing the site with respect to the urban area and a site plan;
- And the characteristics of the source of wastewater to infiltrate.

Pilot Study Conclusions

Significant reduction of bacteriological parameters, such as nitrates, sodium, total hardness, barium, cadmium, aluminum, arsenic, copper, iron, mercury and lead.

The concentrations of chlorides, sulfates, Total Dissolved Solids and manganese, rose above the

NOM-127-SSA1-1994.

Source: Humberto Hernández & Raúl Campuzano, OOMAPAS,SLRC.

MAR PROJECT

On 30 July 2007, the infiltration process begun at an approximate rate of 300 liters per second.

Treated wastewater effluent from the PTAR, with the following paramaters:

BOD_5=46.7 mg/l, SST= 83 mg/l y SS= <0.1 mg/l

In mid July 2007, the work was completed at a cost of $14.22 million pesos (1 million USD approximately), financed by the North American Development Bank (NAD Bank), with funds from the Border Environment Infrastructure Program México-USA (BEIF)

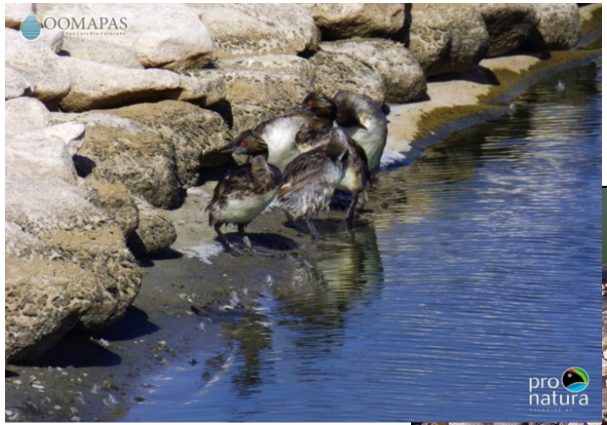
Source: Humberto Hernández & Raúl Campuzano, OOMAPAS,SLRC.

CUCAPÁ WETLAND

The biological design of the Cucapá Artificial Wetland is based on the history of the Colorado River ecosystem, made up of a zone of marshes, a riparian zone, a mesquite forest and the High Plateau of Xerophilous Matorral.

The marshes are currently made up of 8 hectares of Tule as the main species, which performs the primary function of pollutant purification, increasing water quality; this has reduced clogging.

Regarding bird species, there is great interest in the future expansion of the Colorado River Delta Wetland System to host priority bird species (some in danger of extinction).



ECOLOGICAL VISION
FOR THE FUTURE

https://issuu.com/helios_comunicacion/docs/h2o-19-fin

Source: Humberto Hernández & Raúl Campuzano, OOMAPAS,SLRC.

OOMAPAS San Luis Río Colorado

UN WATER 22 MARCH WORLD WATER DAY 2021 VALUING WATER

COLLEGE OF AGRICULTURE & LIFE SCIENCES COOPERATIVE EXTENSION WATER RESOURCES RESEARCH CENTER

iah aih International Association of Hydrogeologists the World-wide Groundwater Organisation

LATINMAR

INSTITUTO DE INGENIERÍA UNAM

THANK YOU

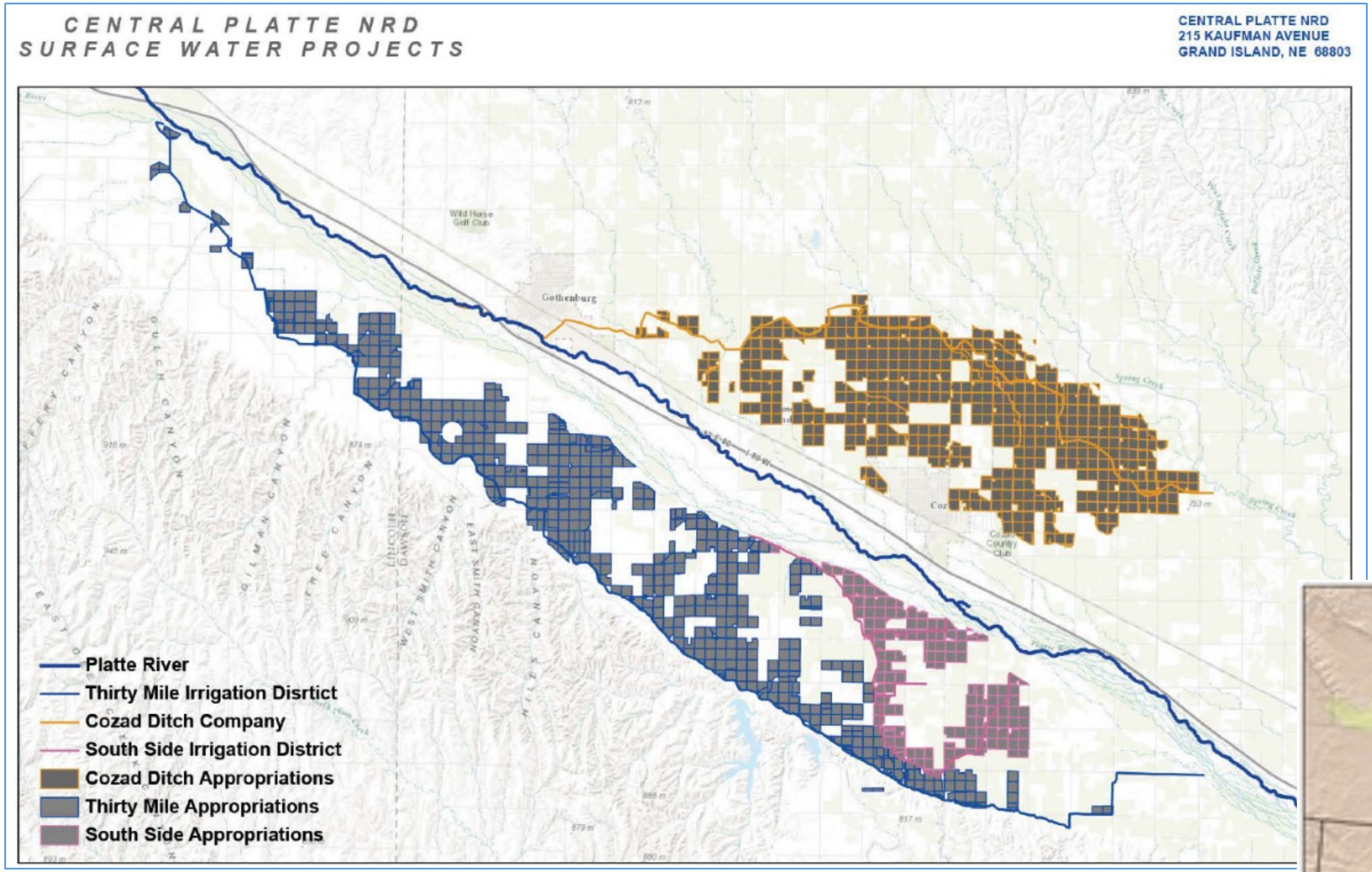
Central Platte River Managed Aquifer Recharge

Crystal A. Powers

Daugherty Water for Food Global Institute

Brandi Flyr, Jesse Strom, Kate Gibson, Nick Brozović

Geography


CENTRAL PLATTE NRD
SURFACE WATER PROJECTS
CENTRAL PLATTE NRD
215 KAUFMAN AVENUE
GRAND ISLAND, NE 68803
Gothenburg
Wild Horse Golf Club
Platte River
Thirty Mile Irrigation Disrtict
Cozad Ditch Company
South Side Irrigation District
Cozad Ditch Appropriations
Thirty Mile Appropriations
South Side Appropriations

Impacts

Average annual groundwater recharge

$11.11\ Mm^3$

Additional monthly Platte River base flow

$150{,}000\ m^3$





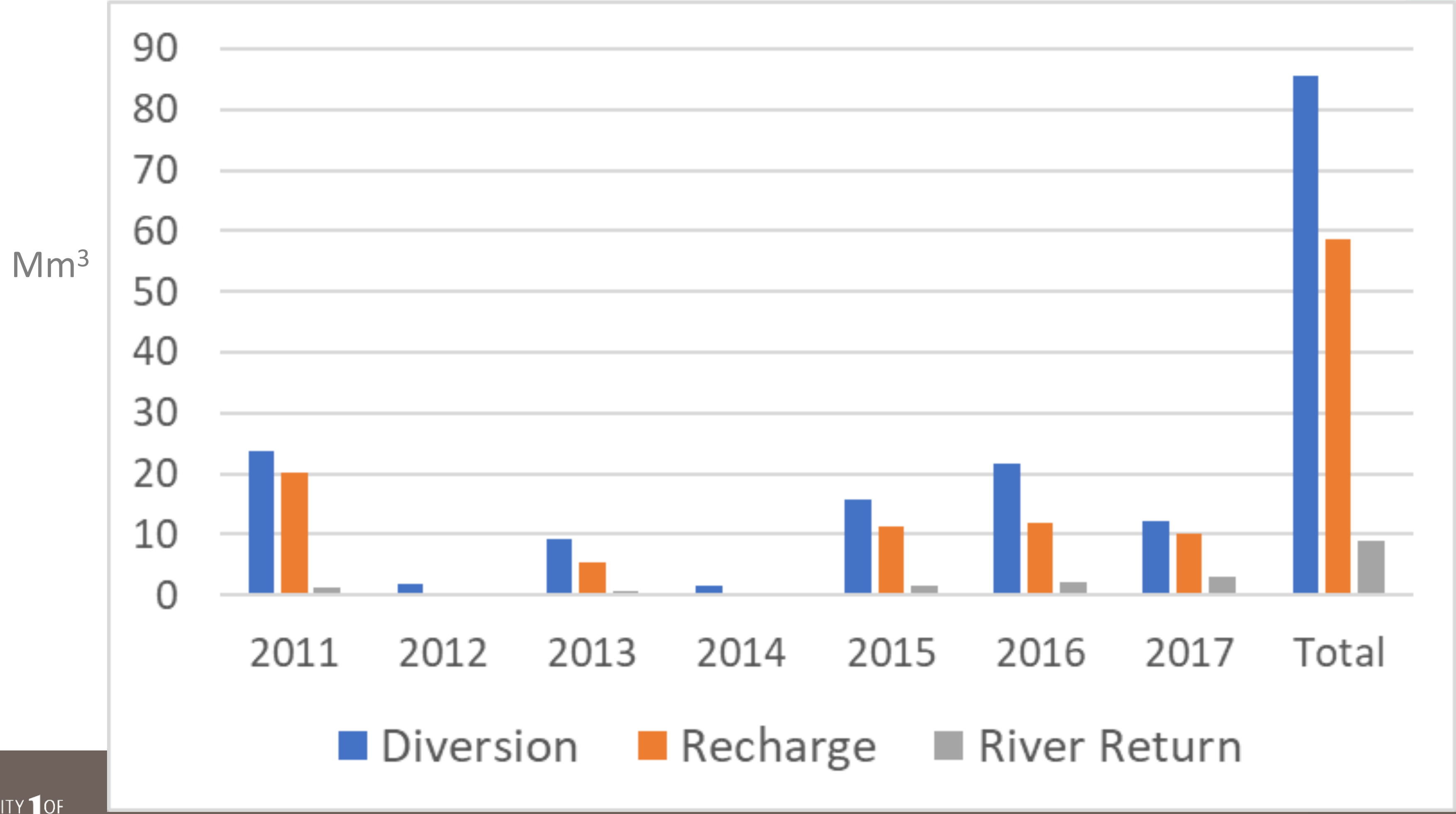
History

(1925): Diversion Point. Canal has been in place and diverting water for 120 years.

(2012): Channel overgrown with trees and channel in disrepair.

(2014): Channel at headworks holding water as designed.

Environmental Sustainability – Aquifer Recharge



Aquifer recharge

Spring 2008 to Spring 2018 Groundwater level change

Economics

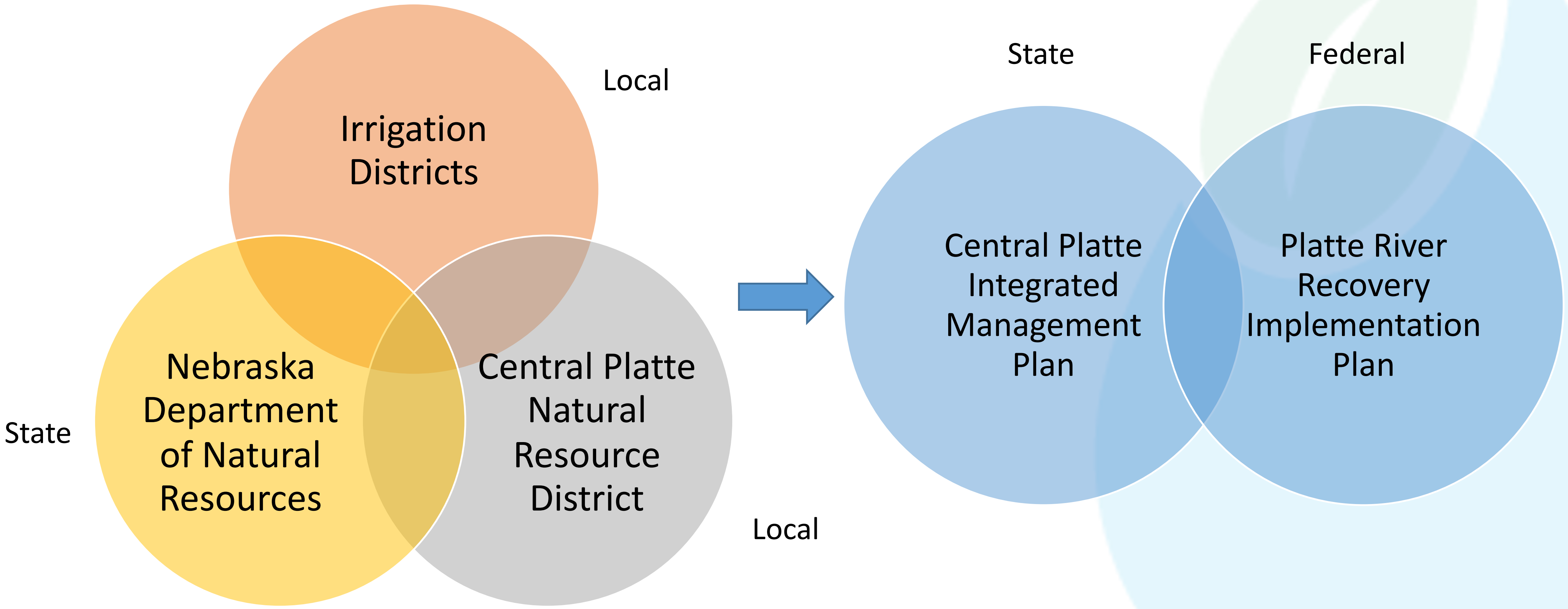
Costs

Capital costs	
Total Design & Construction Cost	$14,426,113
Portion Assigned to Recharge	**$7,213,056**
Project preparation	$4,849,997
Construction: water conveyance	$2,363,059
Annual Operating costs	**$19,936**
Labor	$9,156
Management and maintenance	$10,780

Benefits

Land valuation (2018)	$43.7 million
Annual irrigation value	~$3.33 million

Governance


Irrigation Districts
Local
Nebraska Department of Natural Resources
State
Central Platte Natural Resource District
Local
State
Federal
Central Platte Integrated Management Plan
Platte River Recovery Implementation Plan

30-year interlocal management agreements

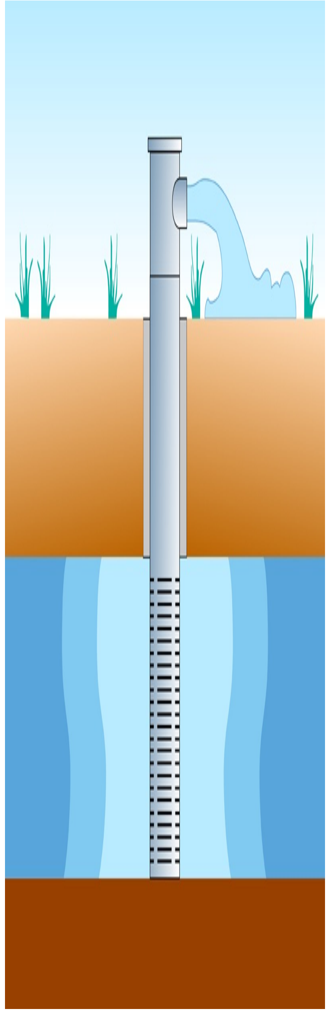
- Water appropriations will be leased from Irrigation Districts to the CPNRD.
- 50% leased interest in real and personal property
- 50% leased interest in water delivery system, including operations & maintenance

waterforfood.nebraska.edu

Thank You

cpowers@nebraska.edu

Achieving Water Supply Reliability at Hilton Head Island, South Carolina, USA



Managed Aquifer Recharge (MAR) with Aquifer Storage Recovery (ASR)

….Celebrating World Water Day

22 March 2021

R. David G. Pyne, P.E.
ASR Systems LLC
Gainesville, Florida

dpyne@asrsystems.ws
www.asrsystems.ws

ASR SYSTEMS

Hilton Head Island, South Carolina
A nice place to be

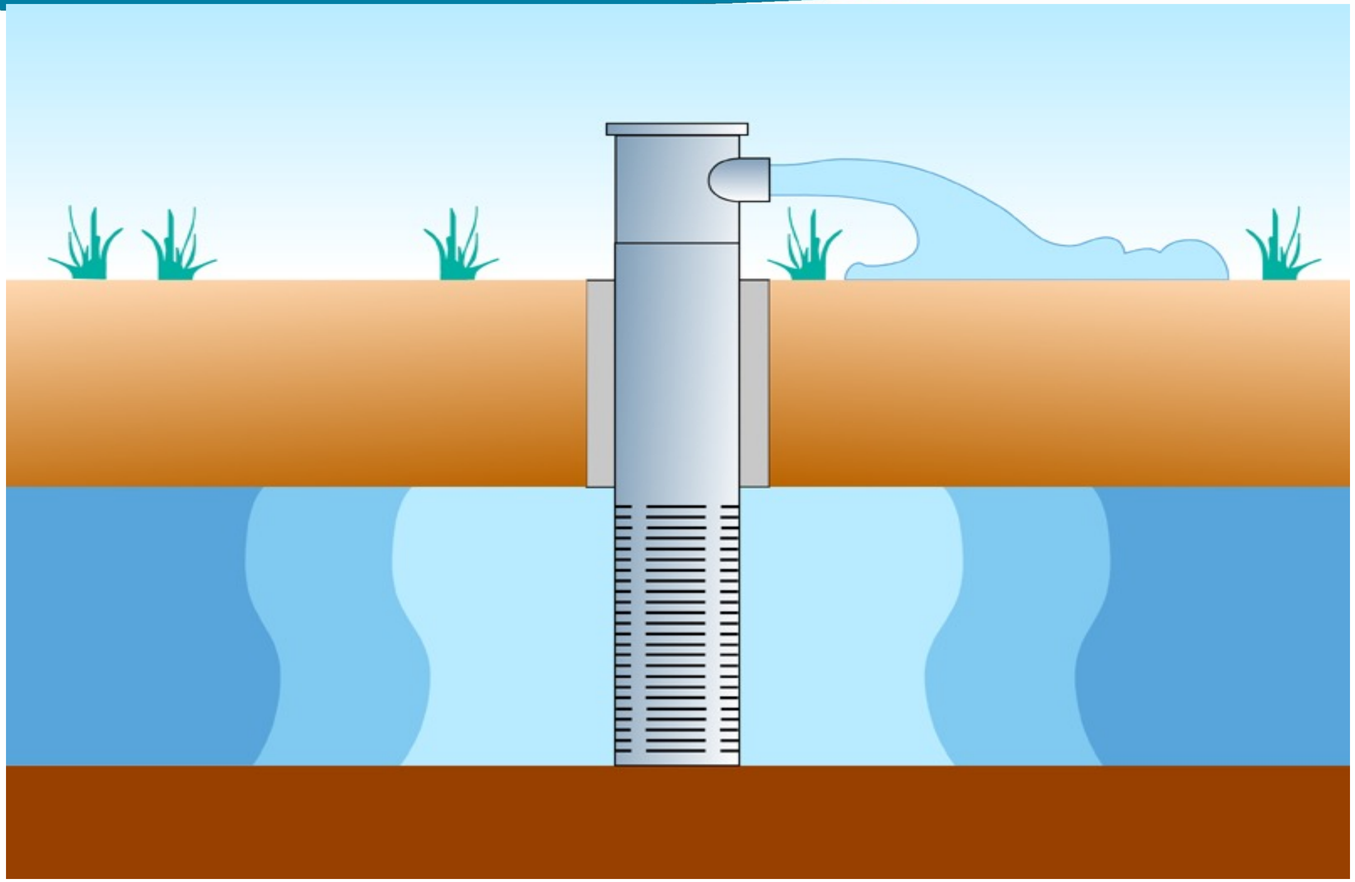


Hilton Head Public Service District Well ASR-1
UNESCO recognition 2021

THE FIRST OF THREE EXISTING ASR WELLS ON THE ISLAND, WITH TWO MORE ASR WELLS PLANNED

Aquifer Storage Recovery (ASR) …

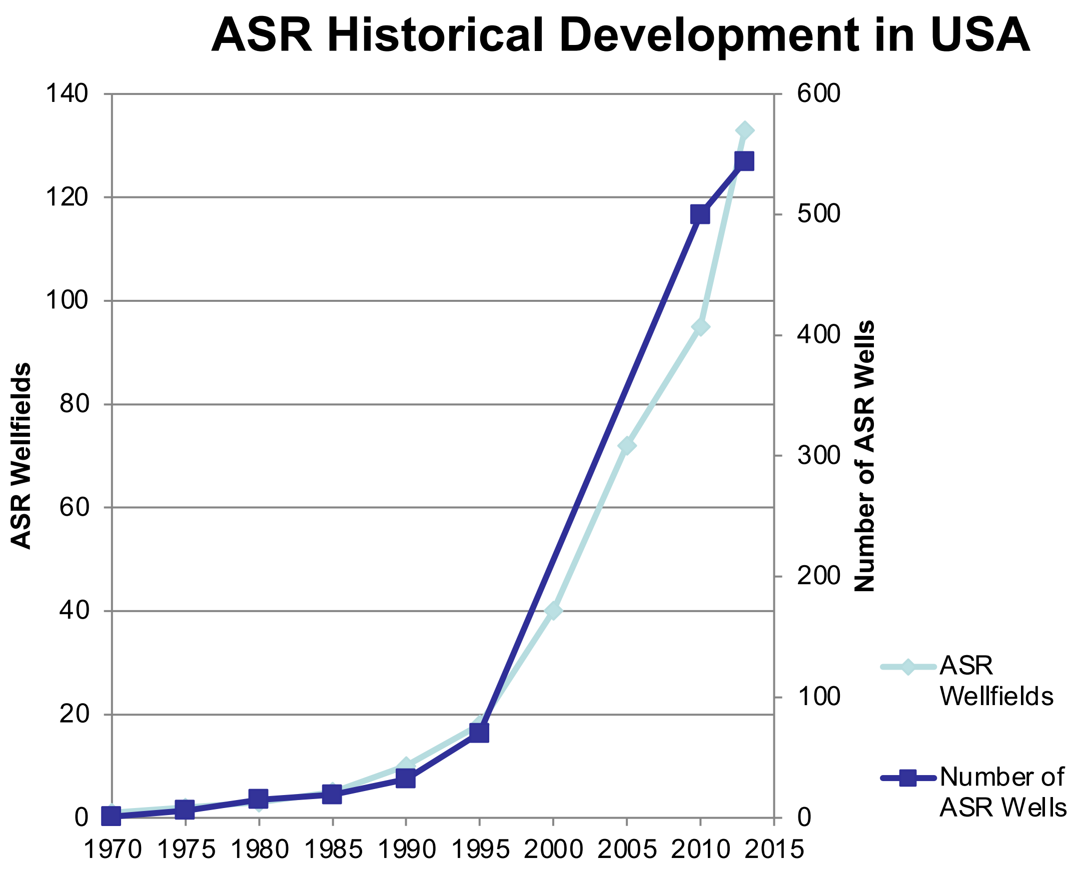
"Managed Aquifer Recharge" Through Wells



Storage of water through a well in a suitable aquifer during times when the water is available, and recovery of the stored water from the same well when needed

ASR Development has been rapid during the past 25 years

- 30 different types of ASR applications
- Many different types of water sources for aquifer recharge
- Storage in many different types of aquifers and lithologic settings



February 2021: About 25 States in USA; Over 160 ASR Wellfields; Over 560 ASR wells

	ASR Wellfields	ASRWells
• Florida	51	123
• New Jersey	24	27
• California	18	68
• Arizona	14	52
• Oregon	11	37
• South Carolina	8	41
• Colorado	6	45
• Nevada	5	91
• Iowa	4	4
• Texas	5	45
• Washington	3	7
• Idaho	2	7
• North Carolina	2	2
• Delaware	2	2
• VA, NM, SD, UT, ME, MN, KS, MS	1 each	9

Global implementation of ASR since 1985 to achieve water supply sustainability and reliability

- Australia
- India
- Israel
- Canada
- England
- Netherlands
- Spain
- South Africa
- Namibia
- United Arab Emirates
- Bangladesh
- And others in development (Kuwait, Taiwan, Indonesia, Qatar, Serbia, Iran)

Adelaide, Australia ASR Well

Several factors have contributed to ASR global implementation

- Economics
  - Typically less than half the capital cost of alternative water supply sources or water storage options
  - Phased implementation

- Proven Success (30 different applications so far)

- Environmental and Water Quality Benefits
  - Maintain minimum flows
  - Small storage footprint compared to surface reservoirs

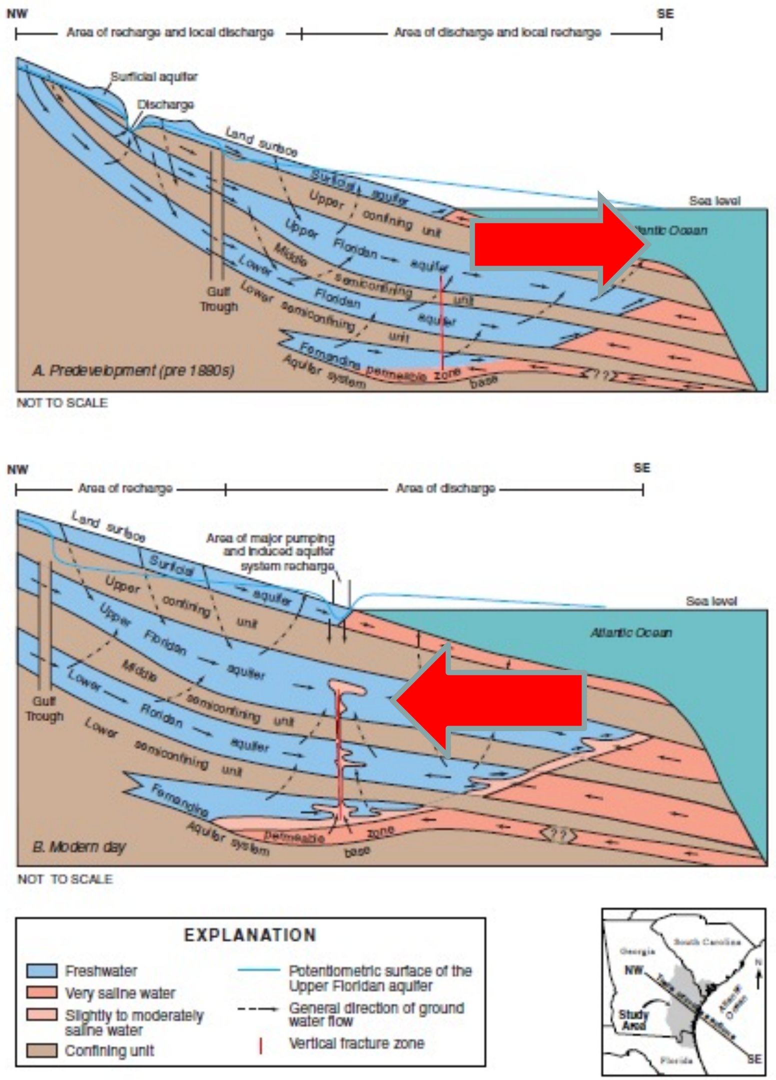
- Adaptability to Different Situations
  - Fresh, brackish or saline storage aquifers
  - Drinking water, reclaimed water, stormwater, groundwater storage

Well ASR-D1 New Braunfels Utilities, Texas

Regional groundwater production near Hilton Head Island has reversed the direction of groundwater flow, causing saltwater intrusion

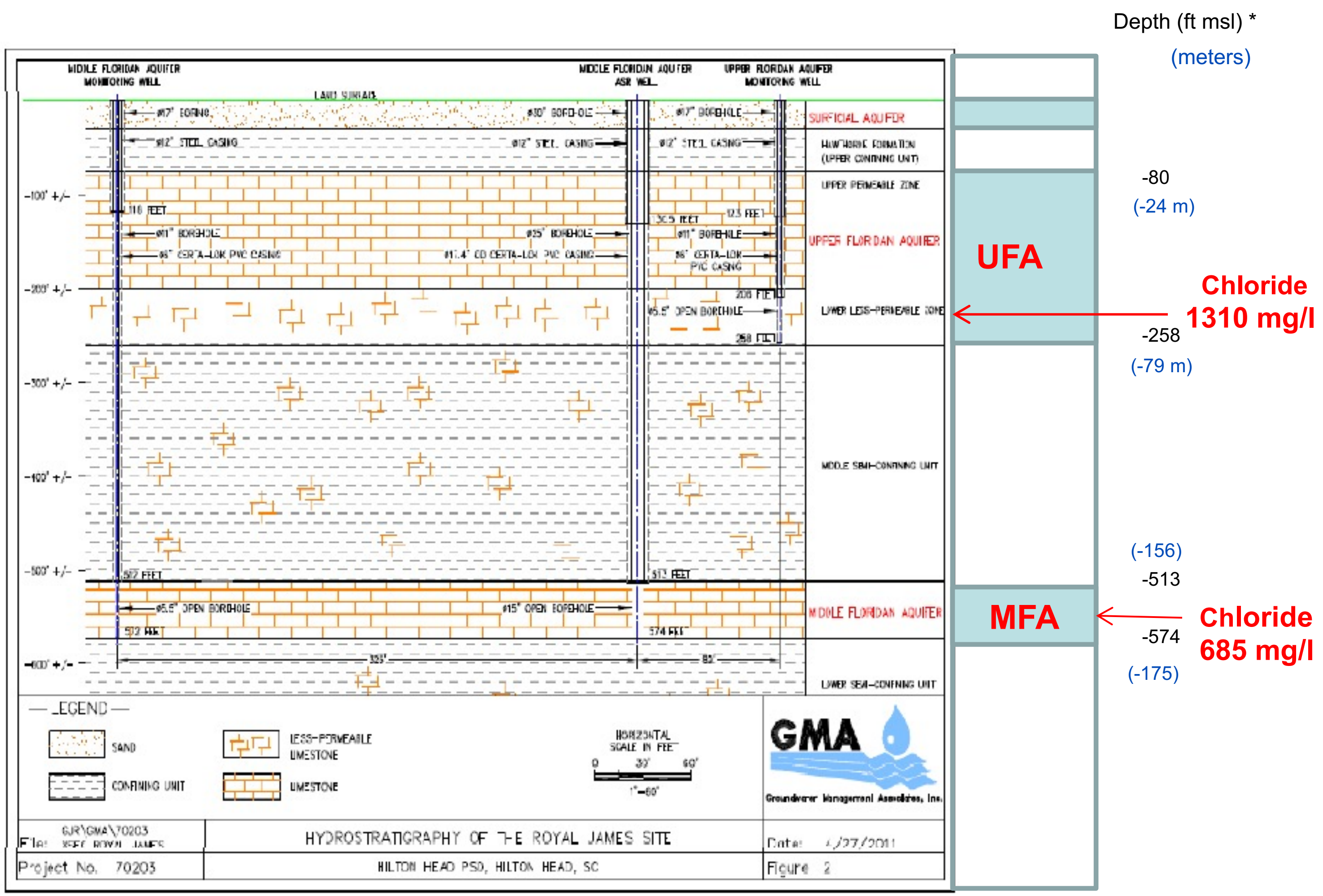
Pre-Development - Discharge to Ocean

Post-Development - Seawater Intrusion



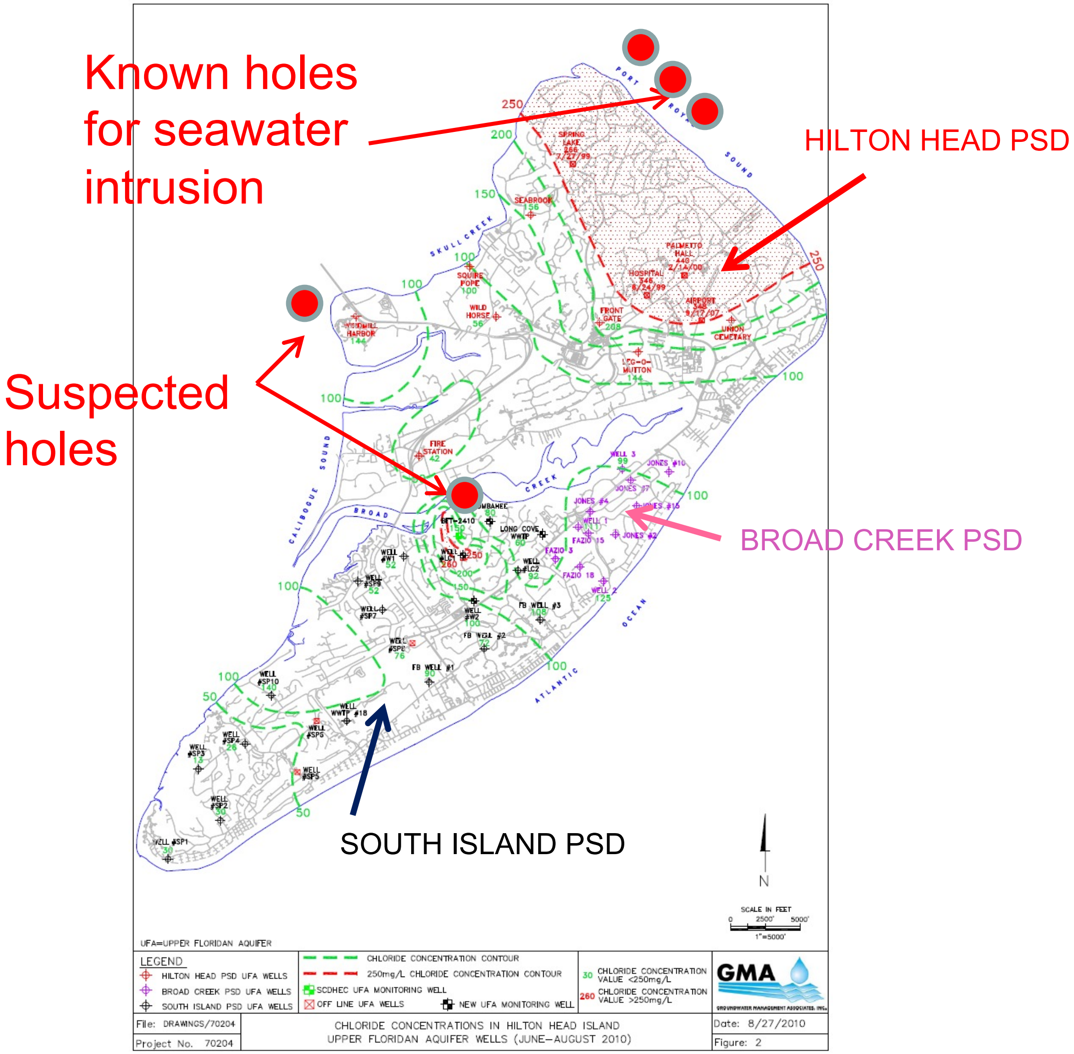
Source: adapted from USGS Report 2005 - 5124

Hilton Head Island
Aquifers and Confining Layers



* Depth at Royal James ASR well

Hilton Head - Upper Floridan Aquifer Seawater Intrusion



- Island is about 19 km (12 miles) long and up to 6 km (4 miles) wide

- Seawater intrusion moving southwest at average rate of about 60 meters/year (200 ft/yr) at the top of the Upper Floridan Aquifer (UFA); more rapidly at the base of the UFA.

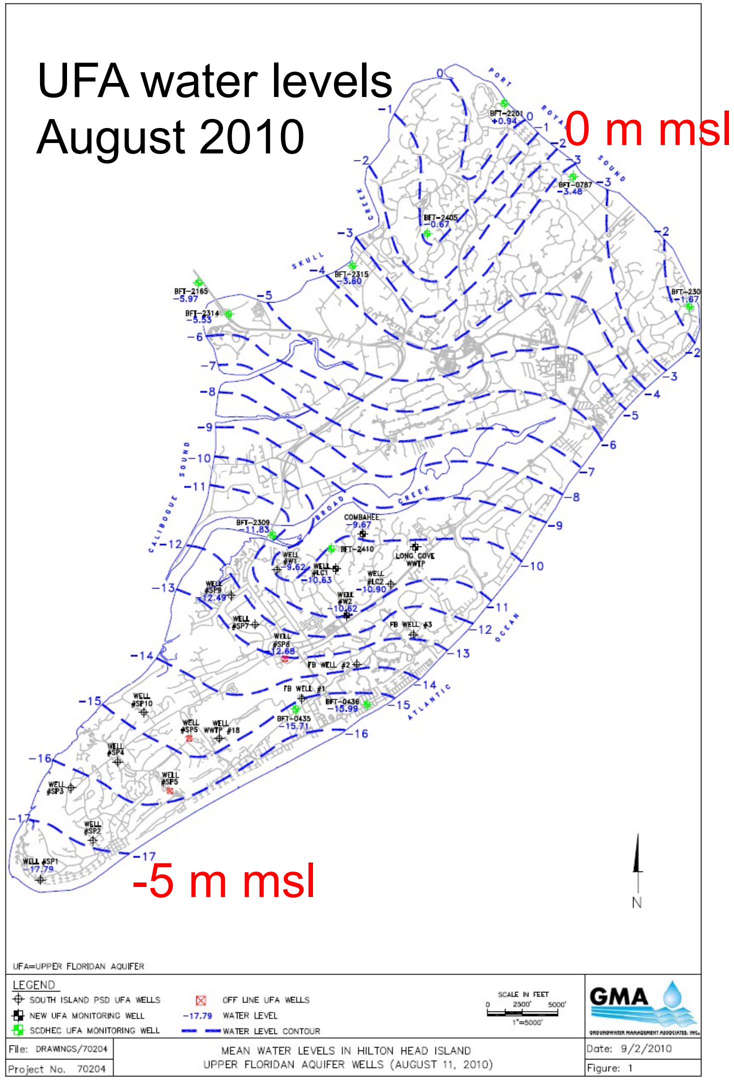
- Seawater is entering the UFA through holes in the upper confining layer

- Within about 20 to 40 years all of the freshwater wells on the island will probably be lost to seawater intrusion.

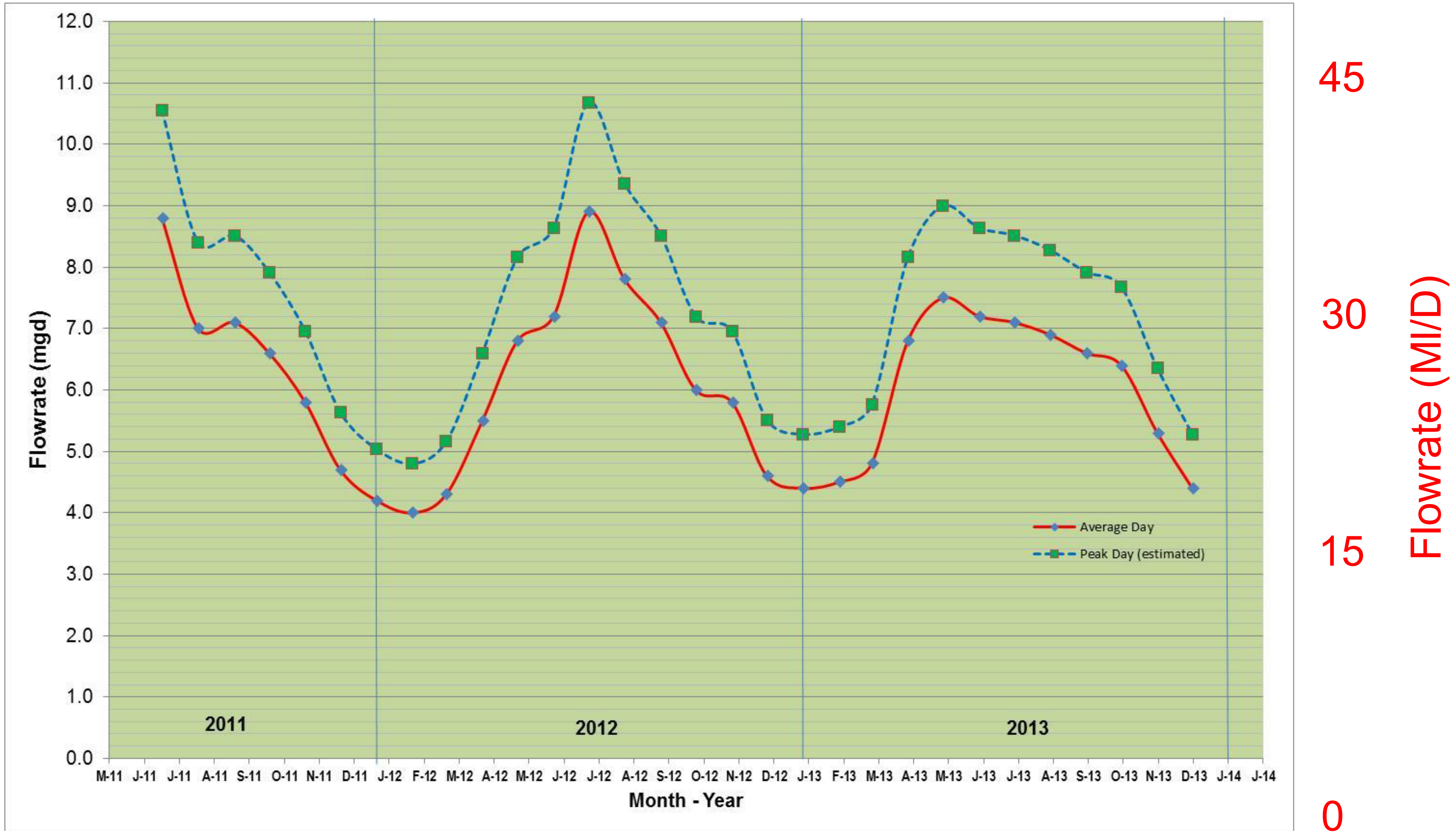
HHPSD Goals: Meet Peak Season Water Demands and Achieve Long-Term Water Supply Reliability

Water Supply Options:

- Import drinking water from the mainland (subaqueous crossing) with lower cost during offpeak months
- Rapidly diminishing supply from UFA production wells due to saltwater intrusion
- Expand existing 4 MGD Reverse Osmosis water treatment plant utilizing brackish groundwater from MFA
- Aquifer Storage Recovery (ASR)
  - MFA √; UFA?
  - MFA well interference (RO/ ASR)?



HHPSD Seasonal Variability in Water Demand



Store water in low demand months. Recover water in peak demand months

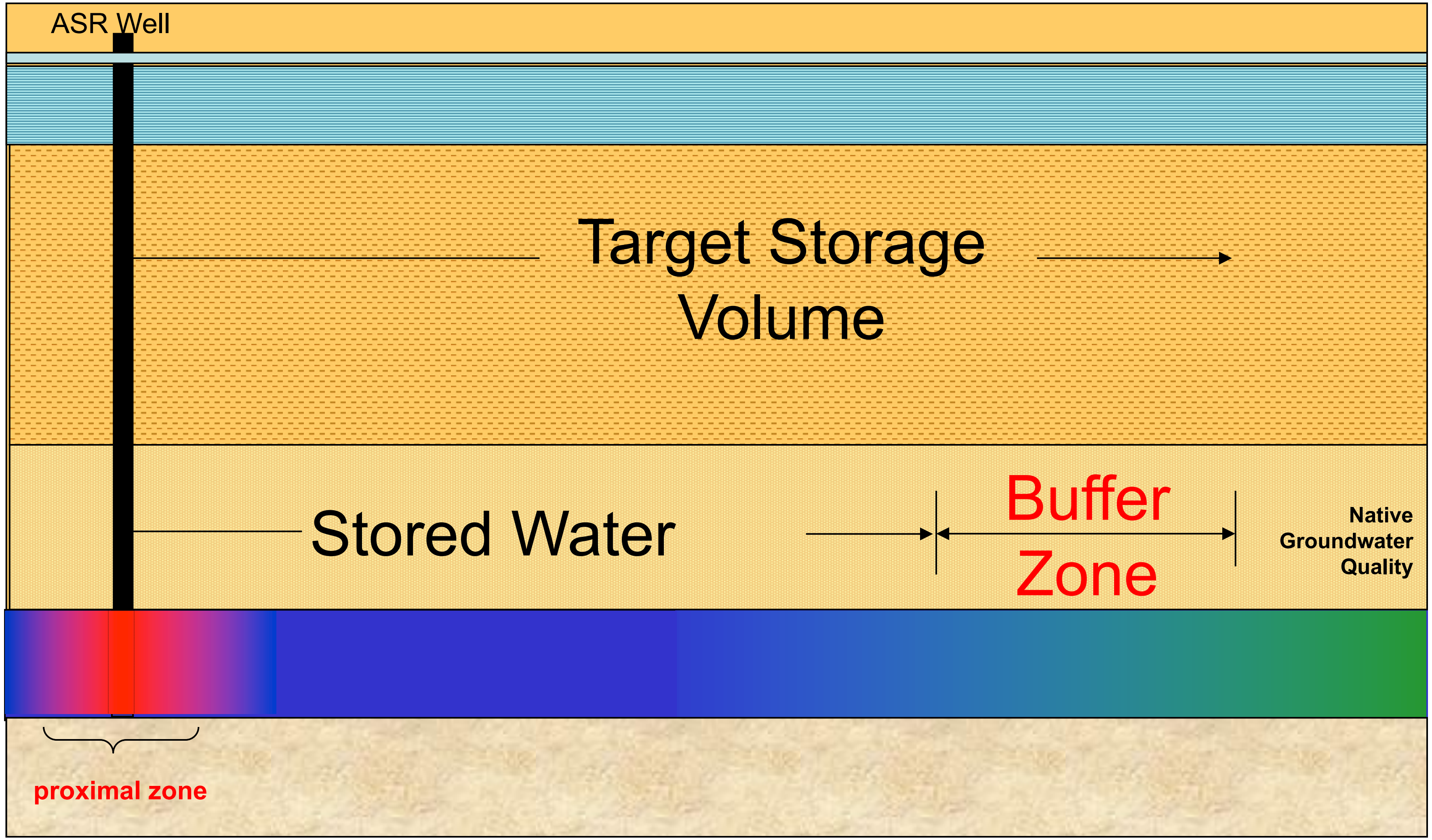
HHPSD Reverse Osmosis Plant

4 MGD Capacity
(15 Ml/D)

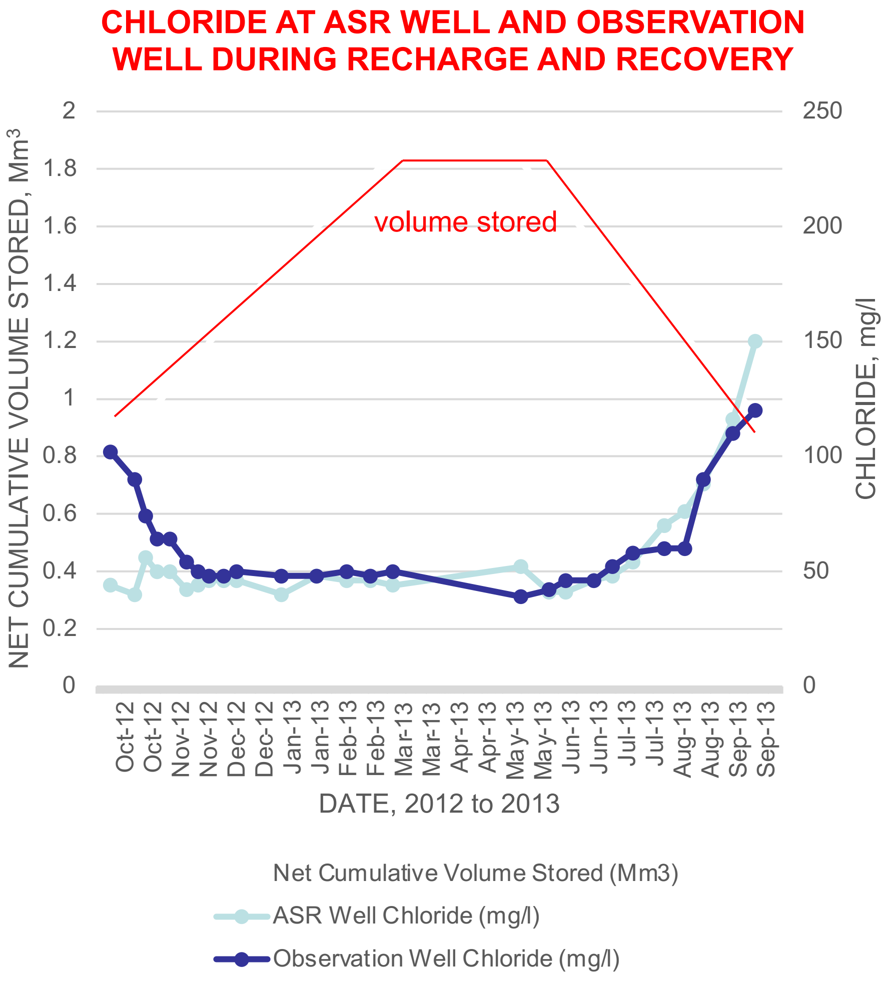
Expandable to
6 MGD

Water Source
from Middle
Floridan
Aquifer (MFA)

ASR TARGET STORAGE VOLUME = 480 MG (1.8 MCM)
(120 days @ 2.0 mgd; plus 240 mg buffer zone)

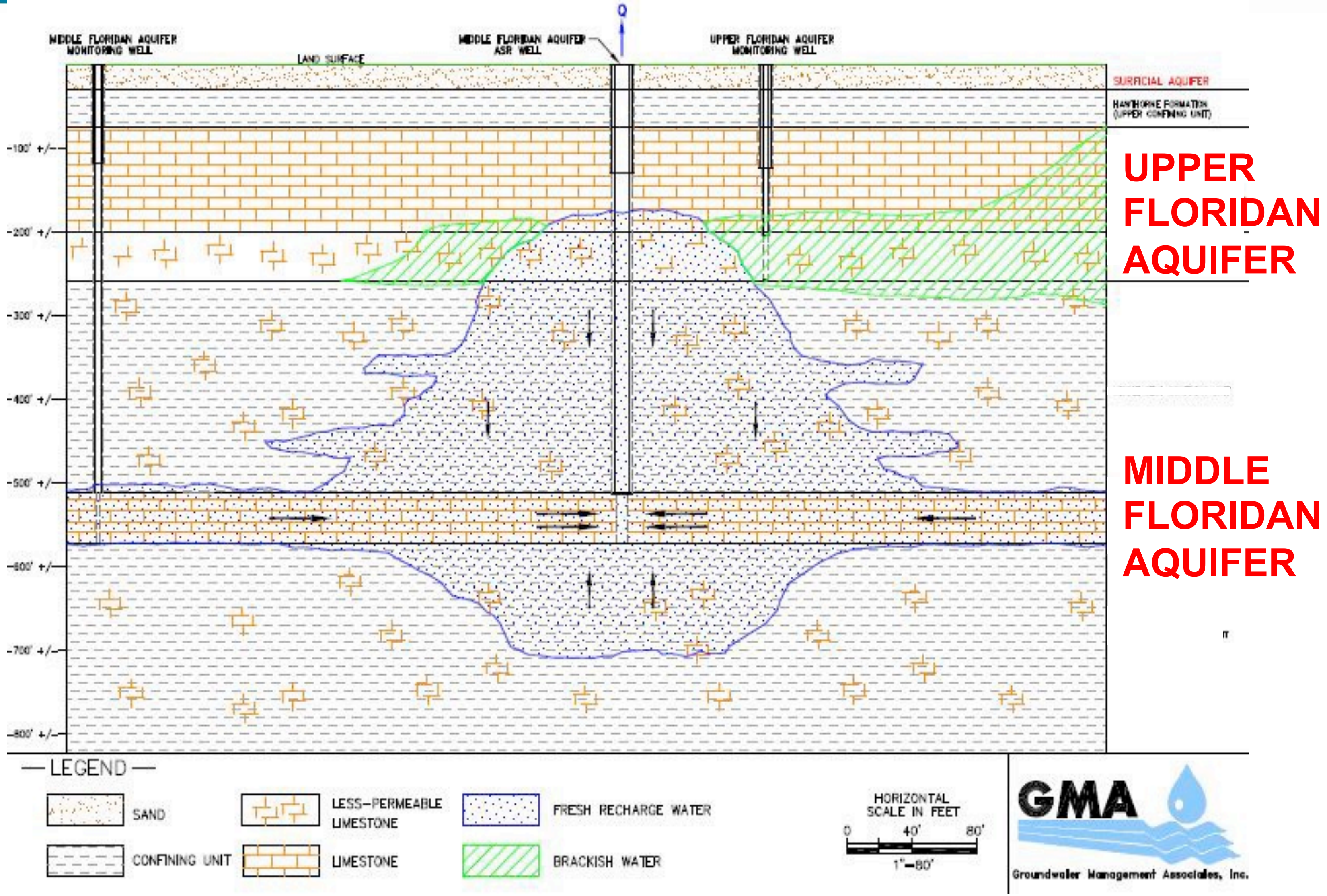


HHPSD Semi-Confining Layer Leakance is Important



- Cycle 1 - October 2012 to September 2013
- Chloride below 150 mg/l during recharge, storage, recovery at ASR well and storage zone monitor well
- Chloride crossover at end of recovery due to downward vertical flow of brackish water from overlying UFA aquifer, next to the ASR well

HHPSD Conceptual ASR Storage Volume



Some Keys to ASR Success

- ASR feasibility study
- Marginal cost water pricing
- Understanding local hydrogeology / geochemistry
- Appropriate engineering design
- Target Storage Volume and Buffer Zone
- Backflushing/ Redevelopment
- Appropriate regulatory framework

ASR Well 29
City of Woodland, CA

2019 ACEC Grand Award Winner

The Arizona Water Banking Authority:
The Role of Institutions in Supporting Managed Aquifer Recharge

Ken Seasholes
Manager of Resource Planning & Analysis, Central Arizona Project

Dr. Sharon B. Megdal
Director, University of Arizona Water Resources Research Center

Managing Aquifer Recharge: A Showcase for Resilience and Sustainability

March 22, 2021

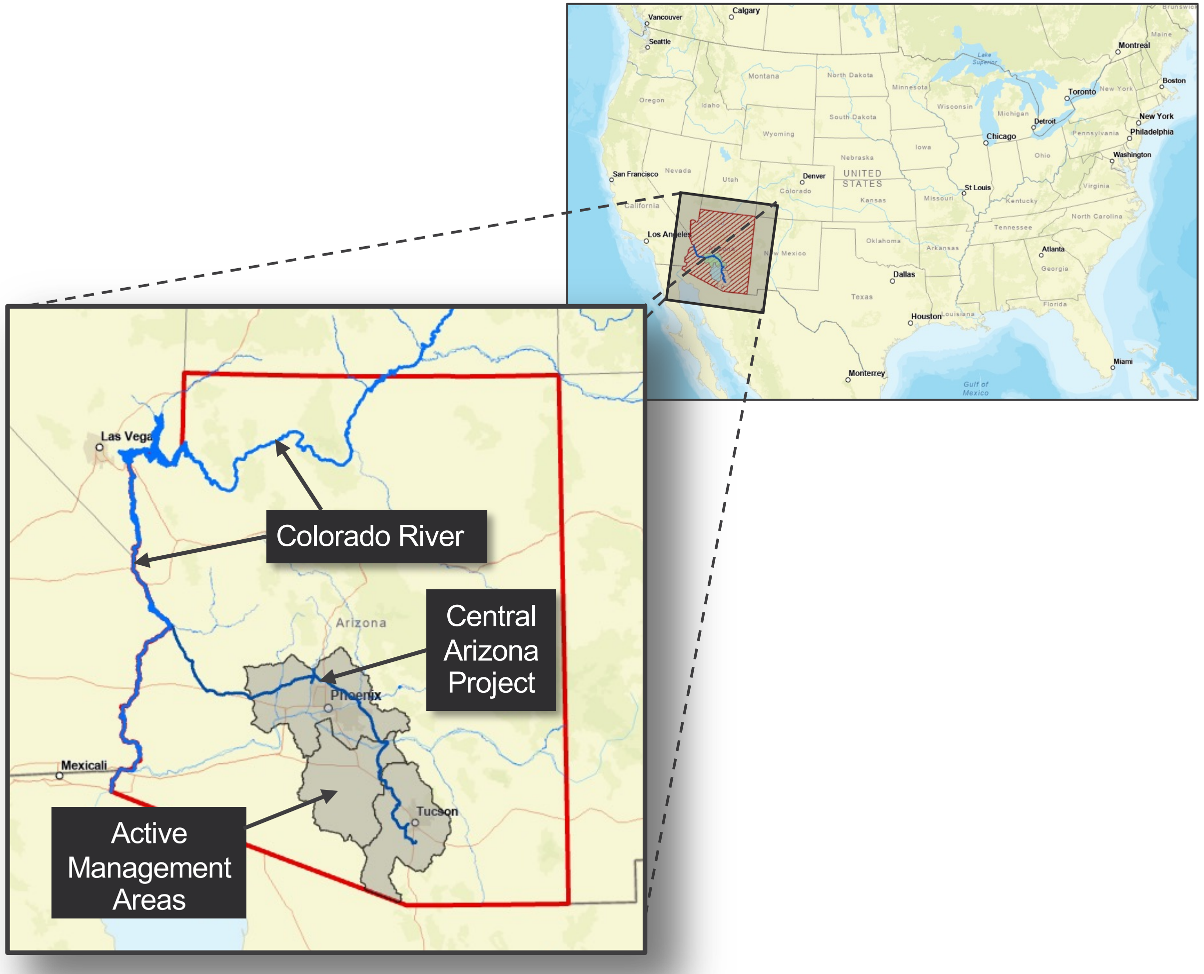
UN WATER
22 MARCH
WORLD WATER DAY
2021 VALUING WATER

COLLEGE OF AGRICULTURE & LIFE SCIENCES
COOPERATIVE EXTENSION
WATER RESOURCES RESEARCH CENTER

iah aih
International Association of Hydrogeologists
the World-wide Groundwater Organisation

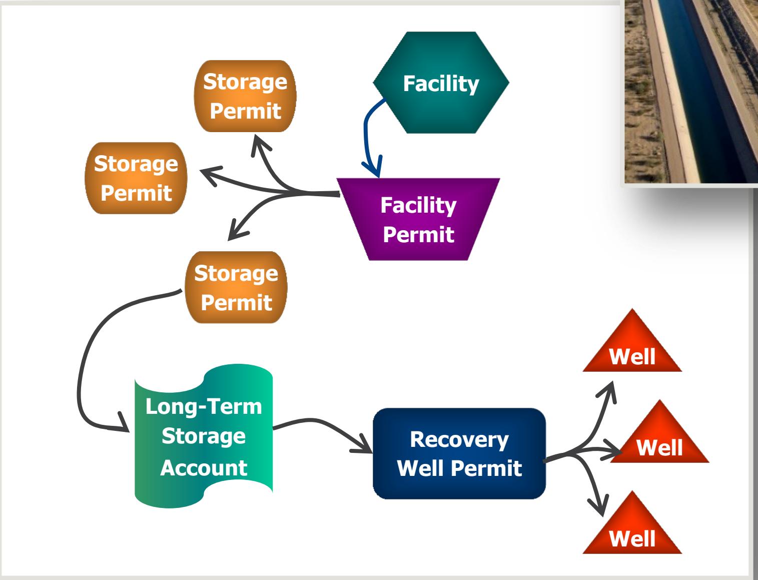
Arizona Water Banking Authority (AWBA)

- Established in 1996
- Governed by a five member Commission
  - Seats reserved to reflect different interests and constituencies
- Three primary policy objectives
  - Put Arizona’s full entitlement of Colorado River water to use
  - Facilitate interstate banking arrangements
  - Increase the reliability of certain supplies impacted by Colorado River shortage



Recharge & Recovery

- Arizona's approach to MAR combines rigorous hydrologic review and monitoring, with accounting that allows differences in the timing and location of recovery
  - Designed to encourage recharge and recovery as water management strategy
  - Particularly well-suited to the hydrogeologic conditions in central Arizona

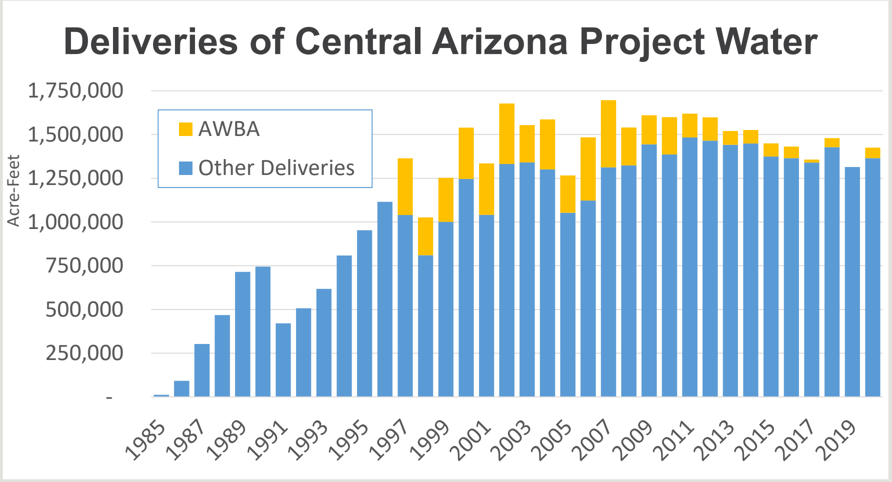


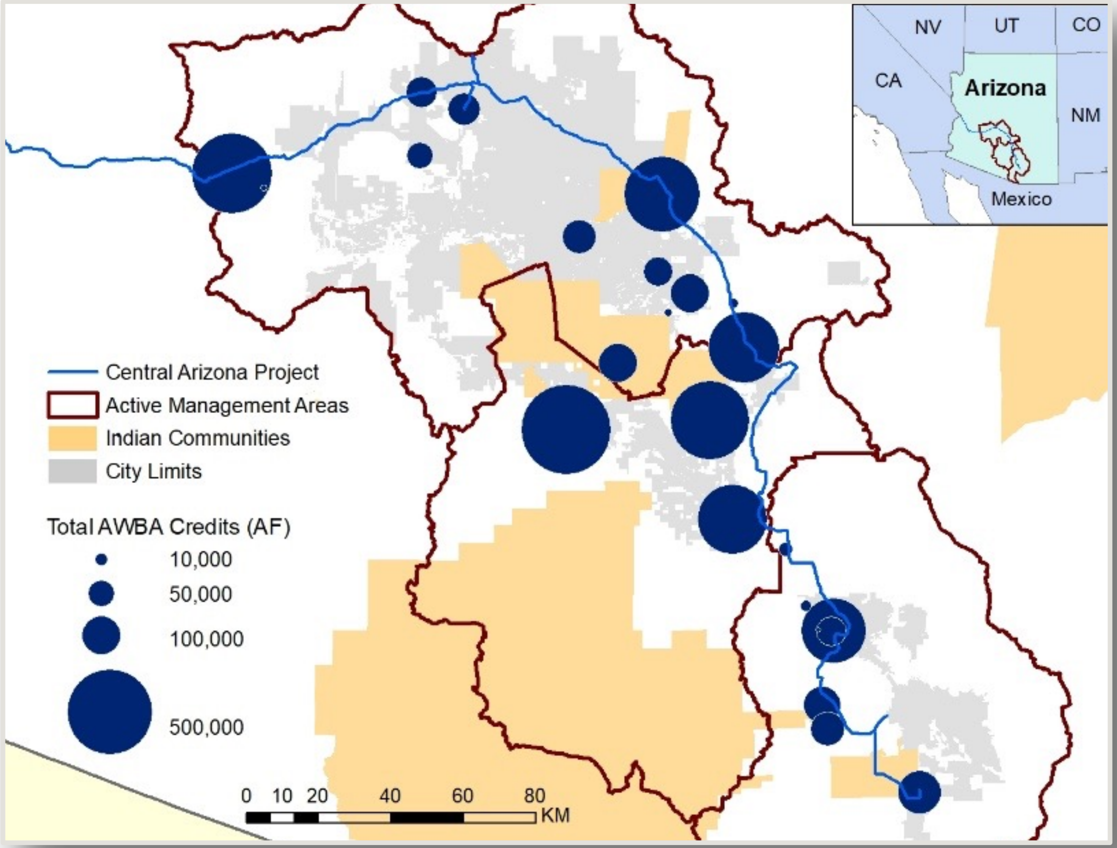
Arizona's Recharge & Recovery Permitting

Superstition Mountains Recharge Project

Storage by the AWBA

- Expenditures of US$413 million through 2019
- 4.3 million acre-feet (5300 MCM) of credits*





Location of Water Storage by the AWBA

*includes credits earned at Groundwater Savings Facilities

Questions?

Arizona Water Banking Authority: www.azwaterbank.gov

Arizona Department of Water Resources: www.azwater.gov

Central Arizona Project: www.cap-az.com