Water Reuse in the Chesapeake Bay Regions: Issues and Challenges

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Water Reuse Seminar
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JOHNS HOPKINS / MWH ALLIANCE
RESEARCH LABORATORY

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Presentation Overview

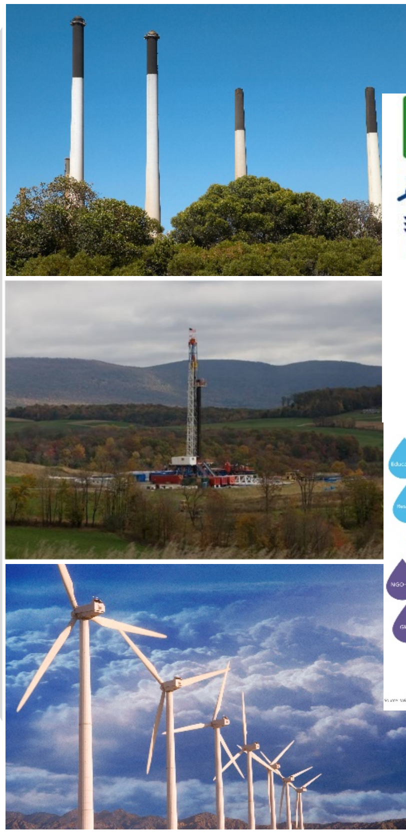
- Thinking about water in a different manner.
- Water reuse nationally and in Chesapeake region.
- Research on nutrient loading.

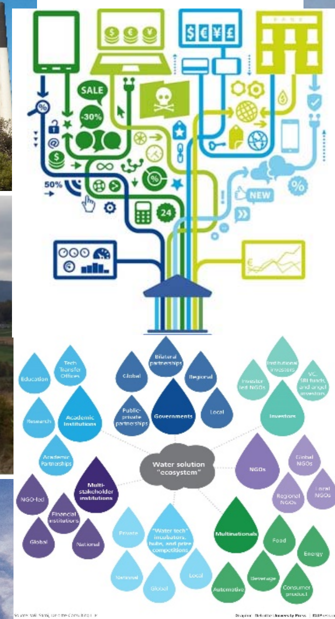
The Water, Energy and Food Nexus

Water for energy

Energy for water

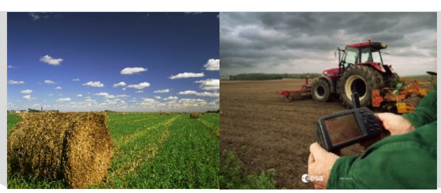
Water is needed to generate energy



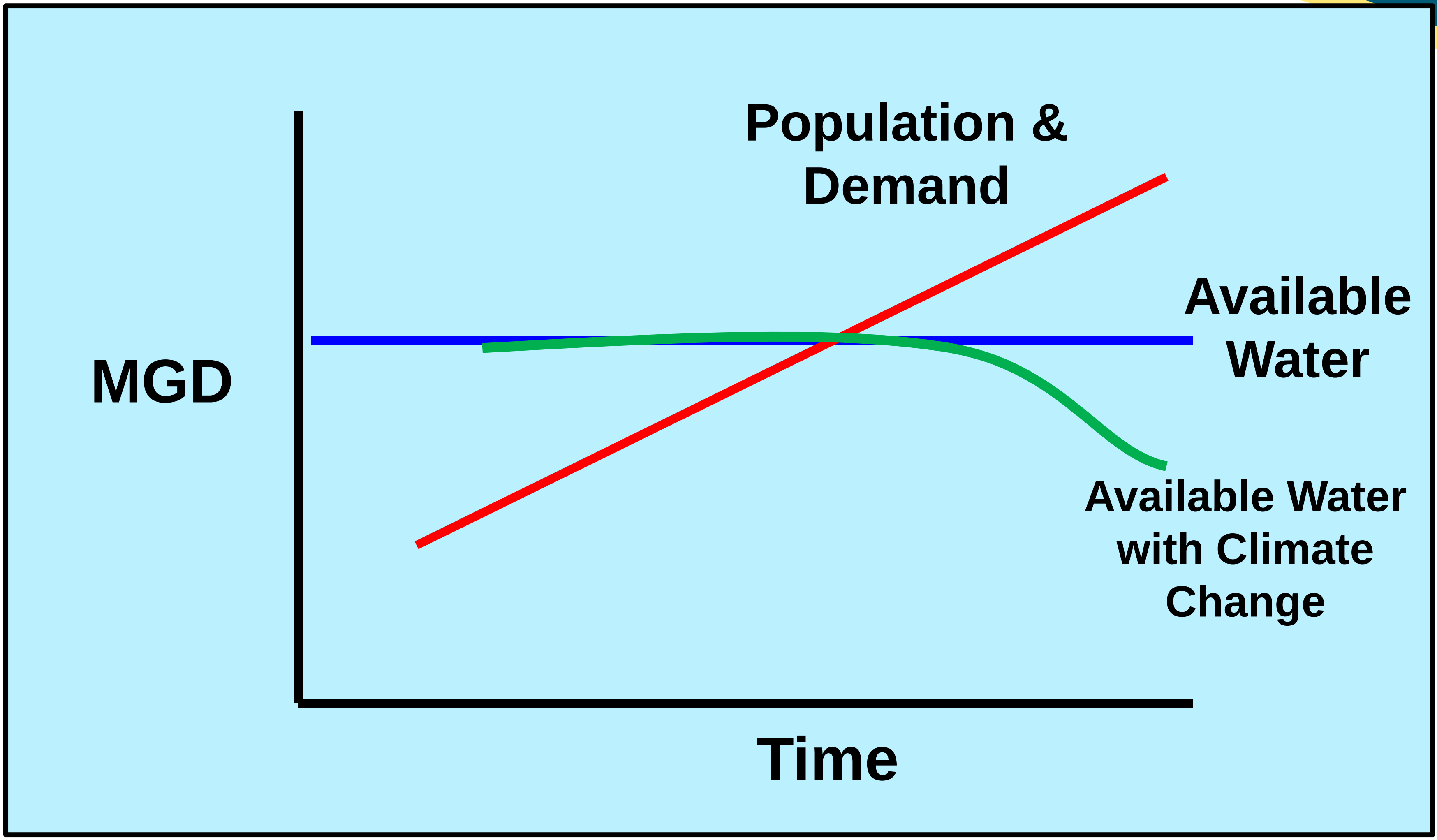


Energy is needed to extract, treat and transport water

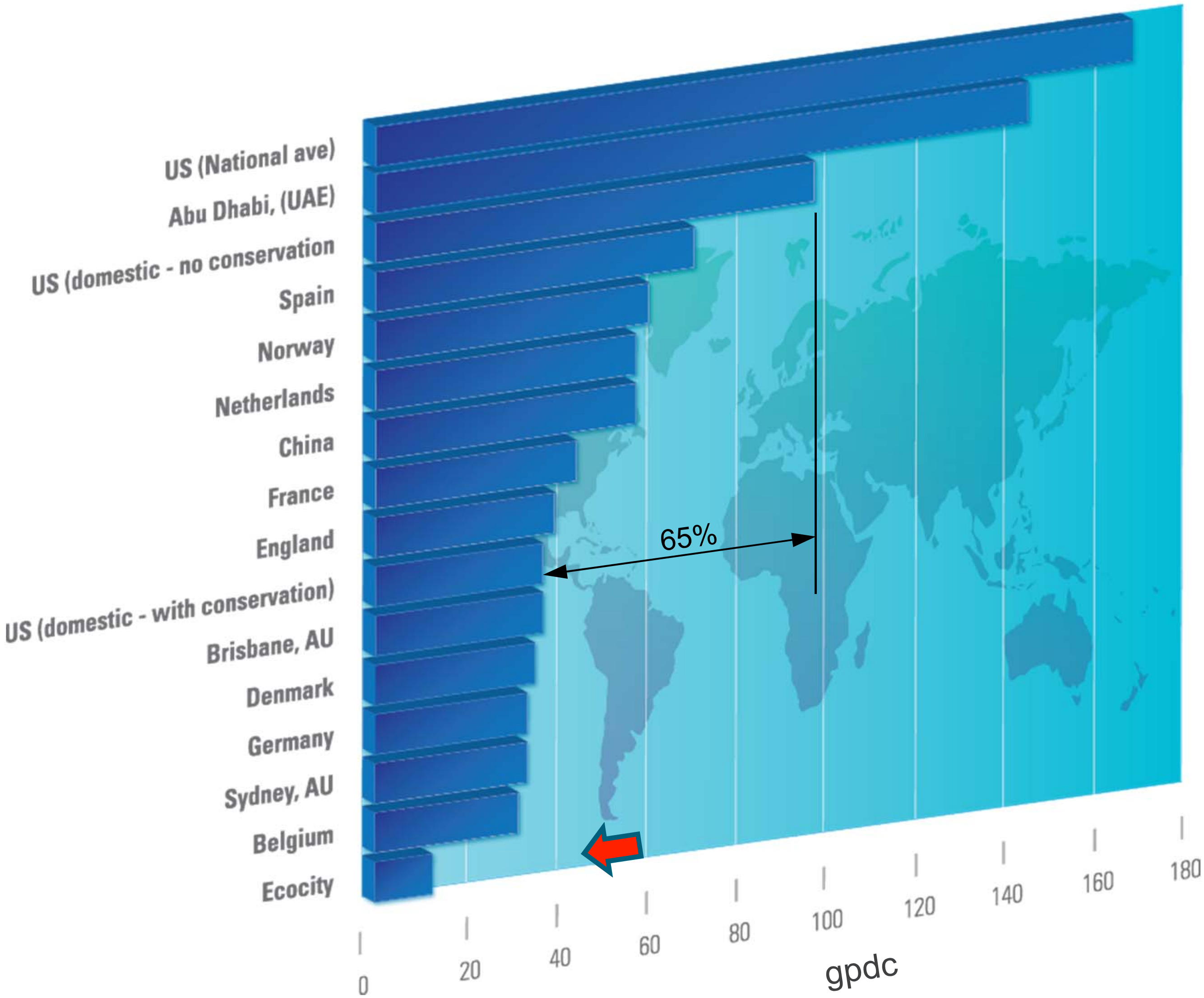
Water and energy for food



Population Is a Key Factor in the Water Scarcity Paradigm

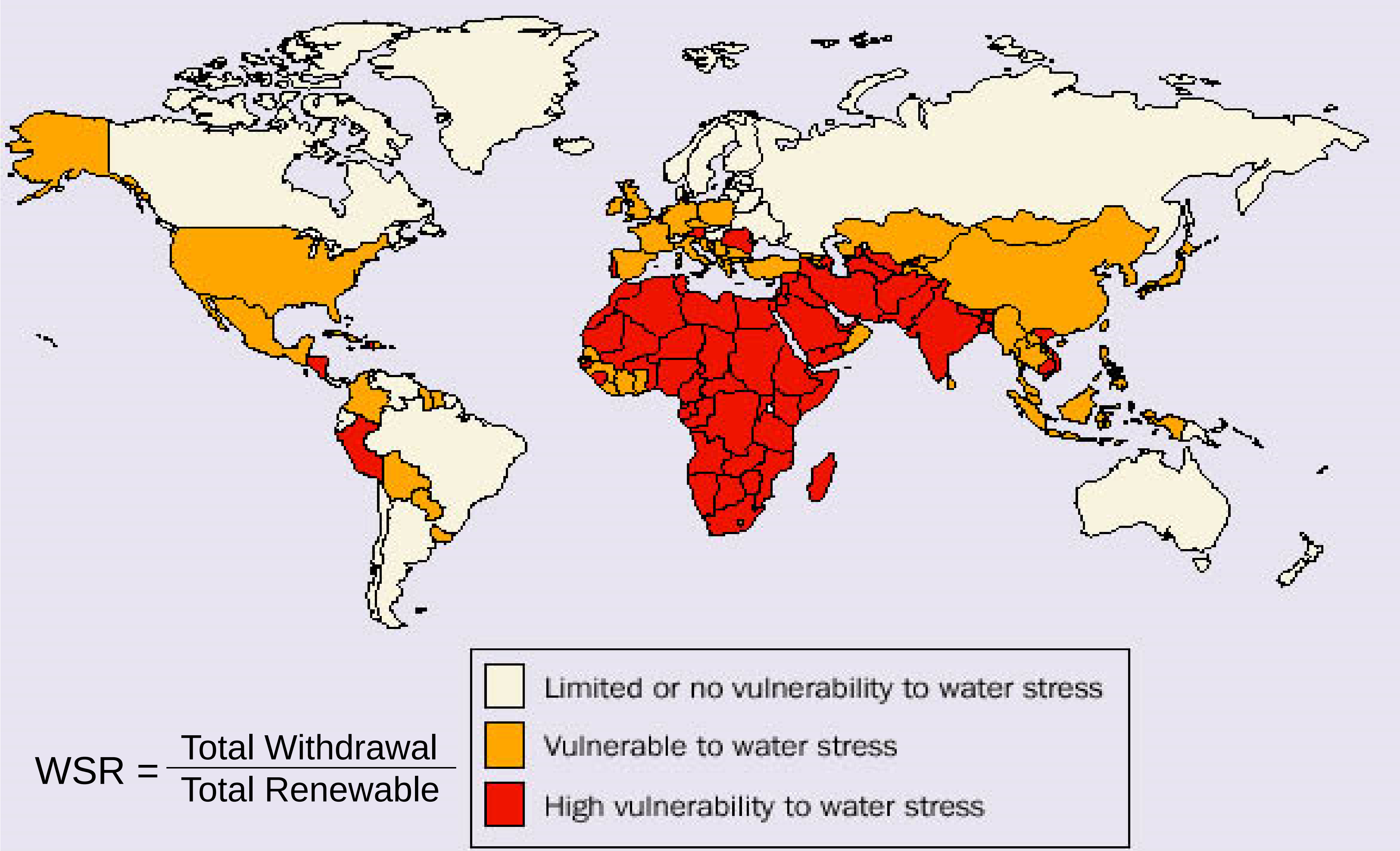


We MUST Reduce Our Demand for Water



Adapted from: Novotny et al., 2011

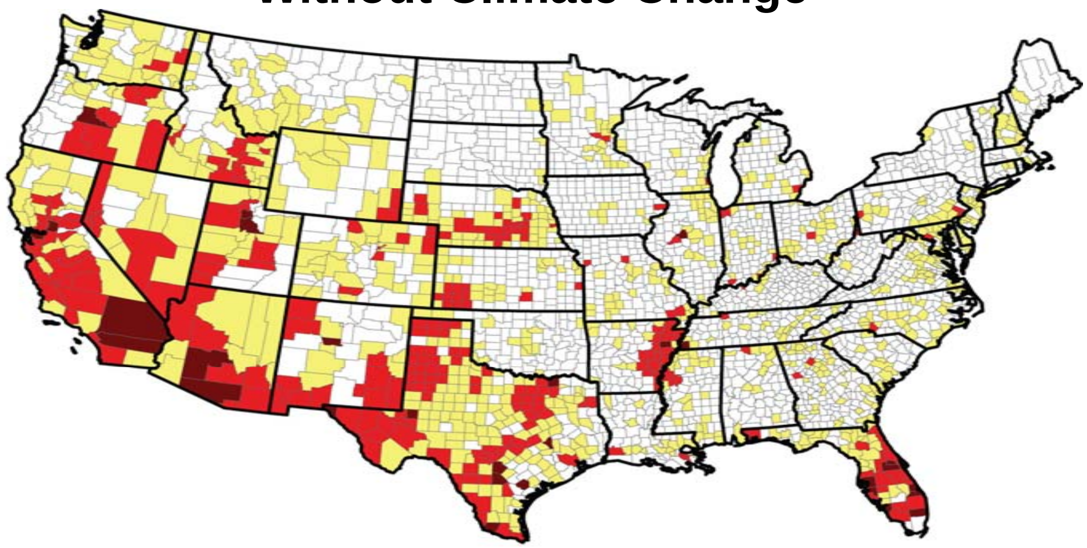
World's Current Vulnerability to Water Scarcity



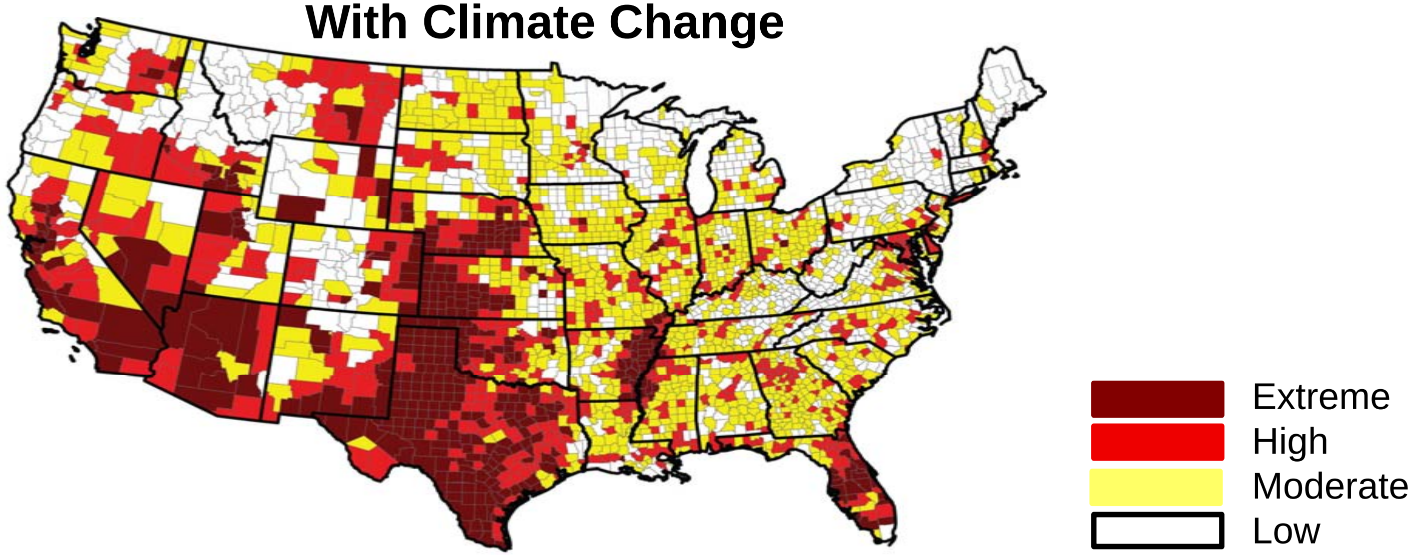
$$WSR = \frac{\text{Total Withdrawal}}{\text{Total Renewable}}$$

2050 Water Stress Index

Without Climate Change



With Climate Change



Scarcity is the "New Normal"

Challenges Include:

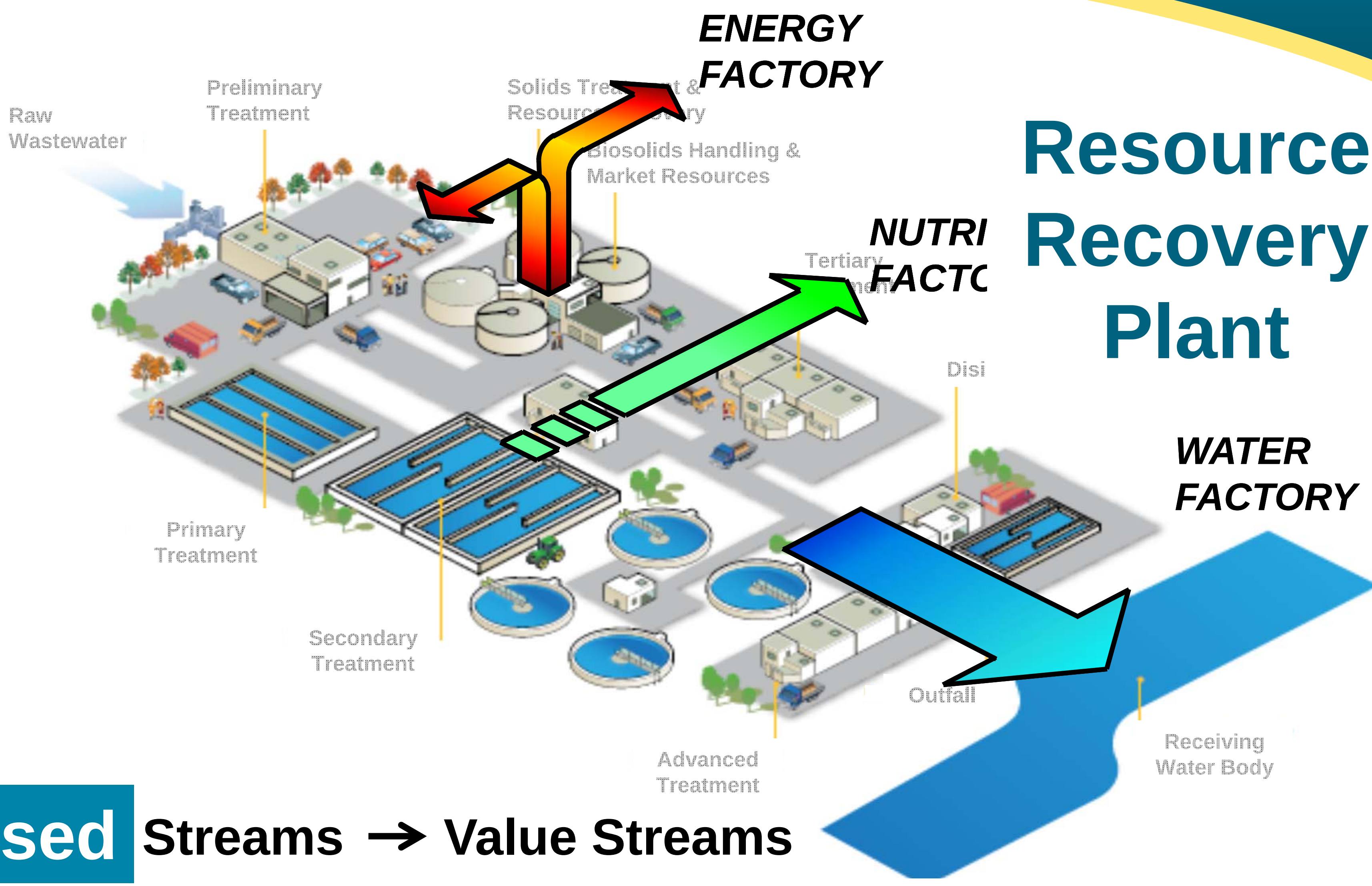
- Climate change impacts
- Water shortages/drought
- Catastrophic events
- Degradation of water quality
- Reliability and redundancy limitations
- Population growth w/ reduced consumption
- Demand for lower-cost solutions

Sustainability of Water Supplies is the "New Normal"

www.blue-economy.ca

- Adaptable to climate change
- Drought-proof
- Robust and secure
- Superior water quality
- Reliable and redundant
- Reduced energy
- Affordable

Treating **Used**water: Responding to the "New Normal"



Resource Recovery Plant

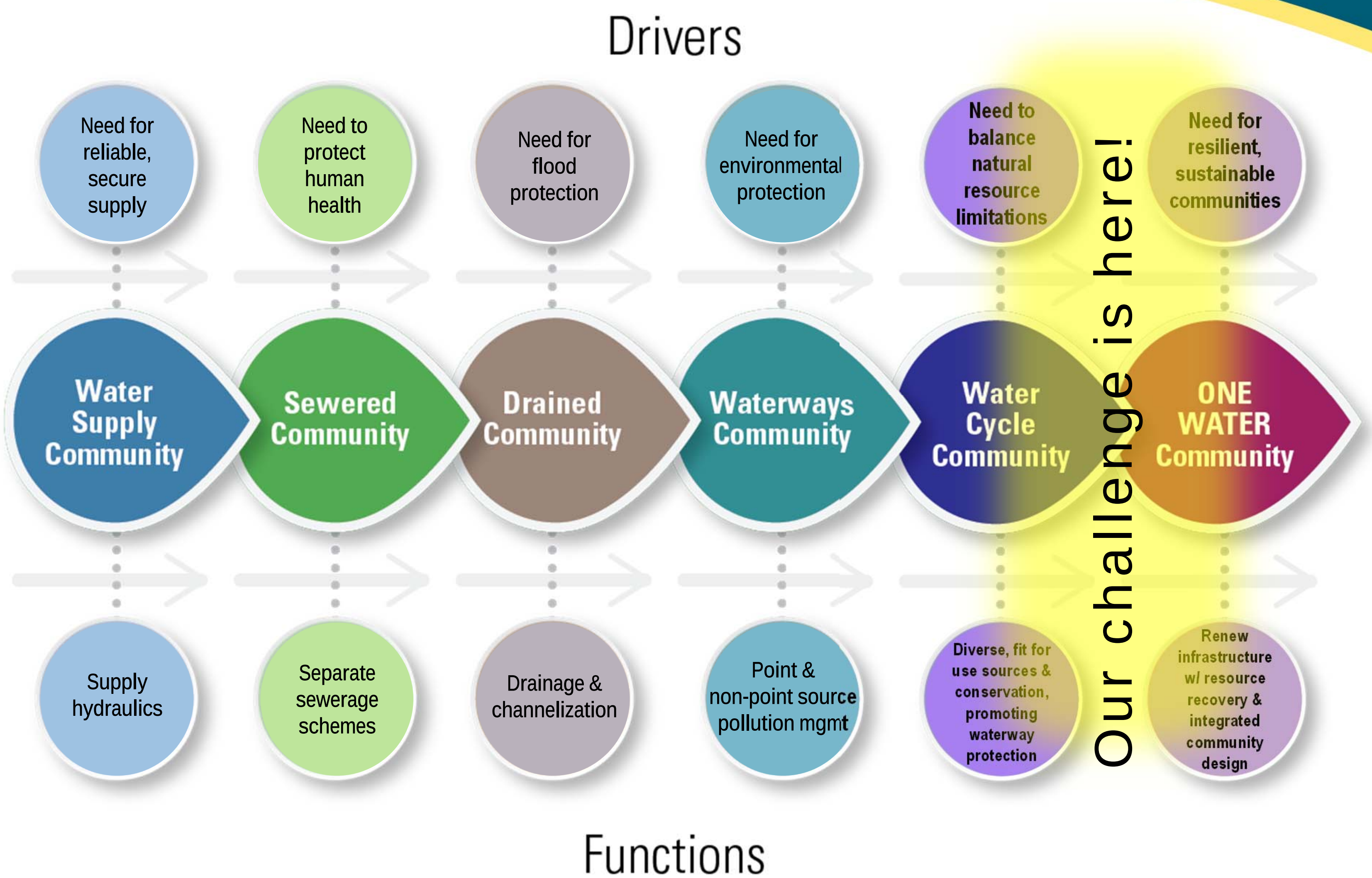
Used Streams → Value Streams

Then WE Need to Think of Water Differently!

- Drinking water
- Wastewater
- Industrial water
- Seawater
- Rainwater
- Irrigation water

Lawaterkeeper.org

"One Water" Culture is Essential



Adapted from: Howe, C., et al (2013)

"New Normal" Demands Water Reuse: Must change our view of water demand!!

Water Footprinting raises our awareness of the true value of water

How Much Water Does It Take?

- **It takes 1,800 gallons of water to produce the cotton in one pair of blue jeans.**
- **It takes 4,000 gallons of water to grow a bushel of corn.**
- **It takes 11,000 gallons of water to grow a bushel of wheat.**
- **It takes 4,000 gallons of water to produce one pound of beef, so it takes 1,000 gallons of water for a Quarter Pounder at McDonald's.**
- **It takes 16.5 gallons of water to manufacture a 12-ounce Coke.**

Challenge

Can you foresee a time when:

1) your organization adapts its practices base on its water footprint?
2) you or your organization makes purchasing decisions based the virtual water embedded in a product?

All Water is Reused

There is no new water!

What is Water Reuse?

The reclamation and treatment of impaired waters for the purpose of beneficial reuse.

WateReuse Association, 2003.

Impaired Waters

- Municipal and industrial wastewater effluent
- Brackish water
- Poor quality groundwater
- Agriculture return flows
- Stormwater
- Frack flowback and produced water

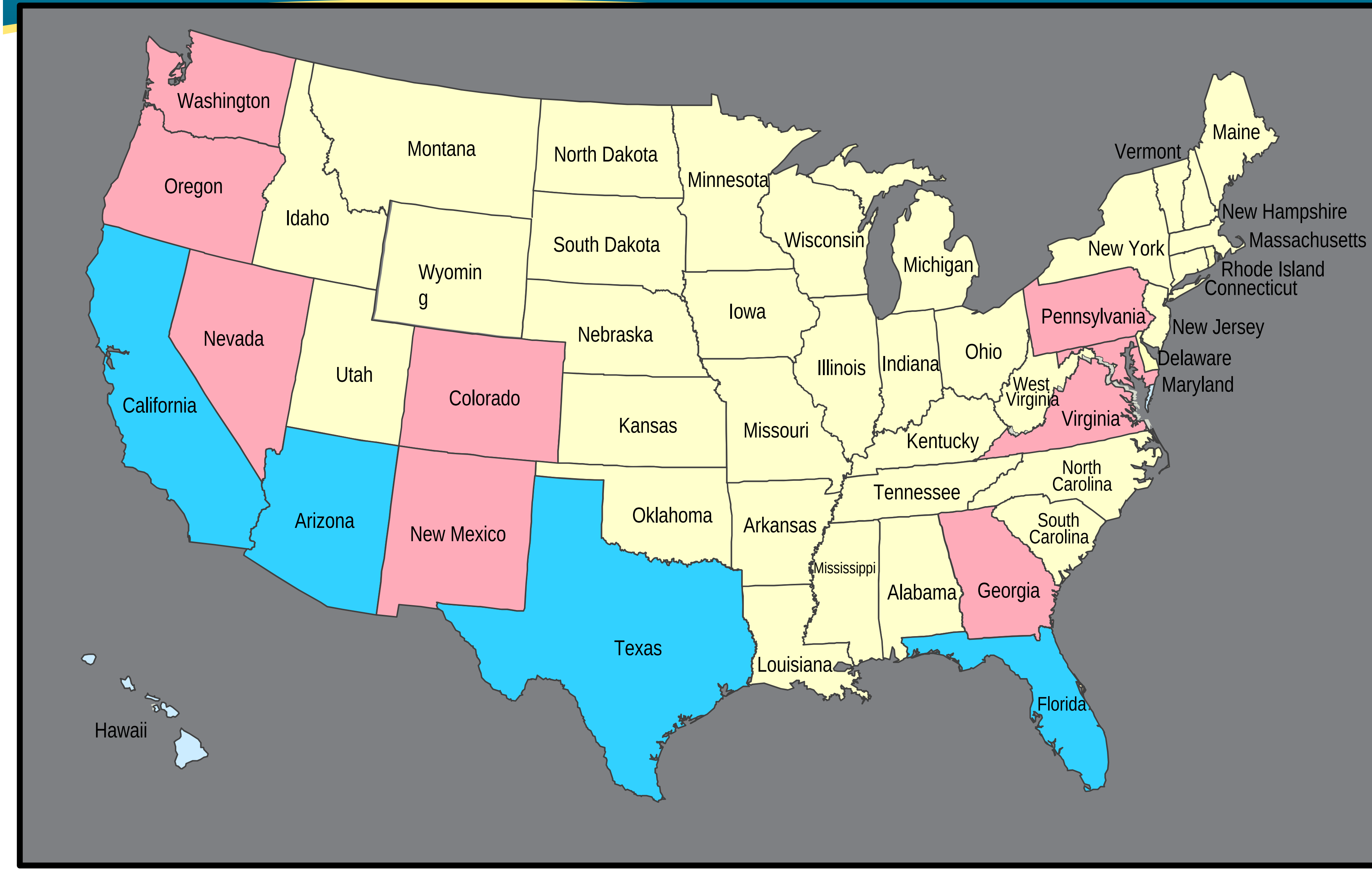
Uses of Reclaimed Water in US and Canada

- Agricultural irrigation
- Landscape irrigation
- Nonpotable urban uses
- Industrial uses
- Impoundments
- Environmental uses
- Groundwater recharge
- Indirect potable reuse
- **Direct potable reuse**

Approximately 90% of Engineered Water Reuse Occurs in Four States

Adapted from Miller, 2013

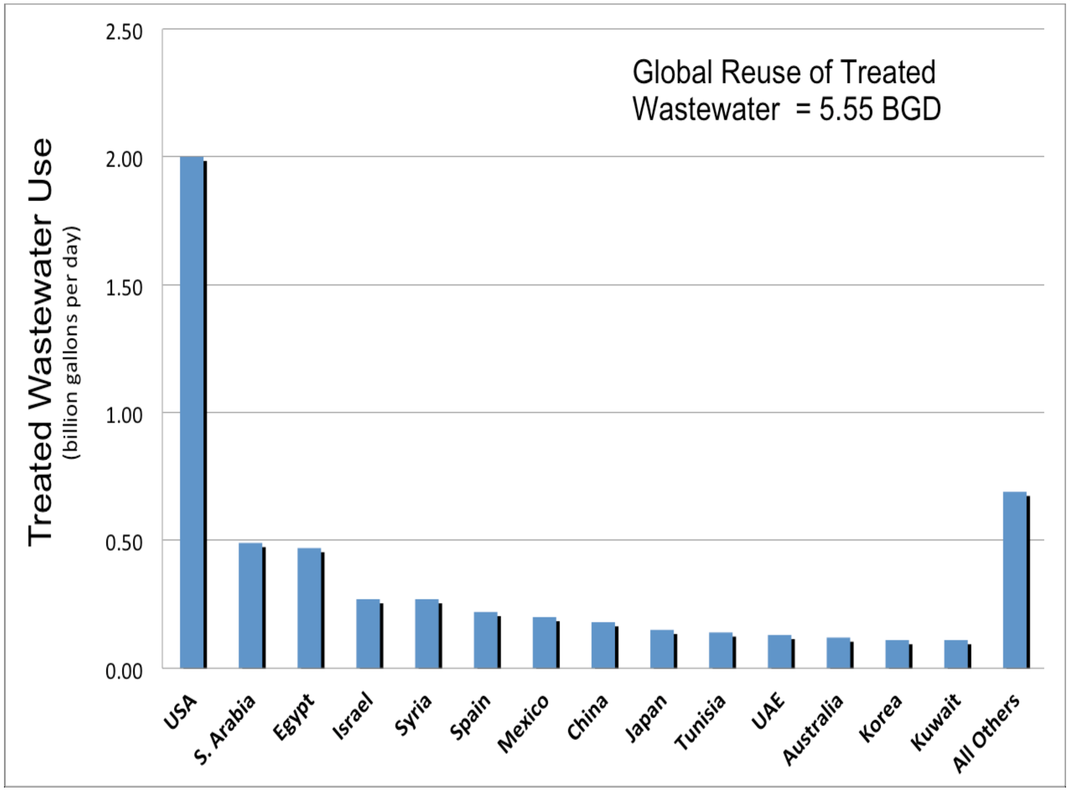
Other States Actively Employing Engineered Reuse



Adapted from Miller, 2013

Estimated Status of Water Reuse

- Reuse practiced in 43 countries, 13 BGD
  - 58 percent using untreated wastewater for irrigation
  - 1.7 BGD reused in US



- Approximately 1,500 water reuse facilities in U.S.
  - Only 7-8% of wastewater is currently reused

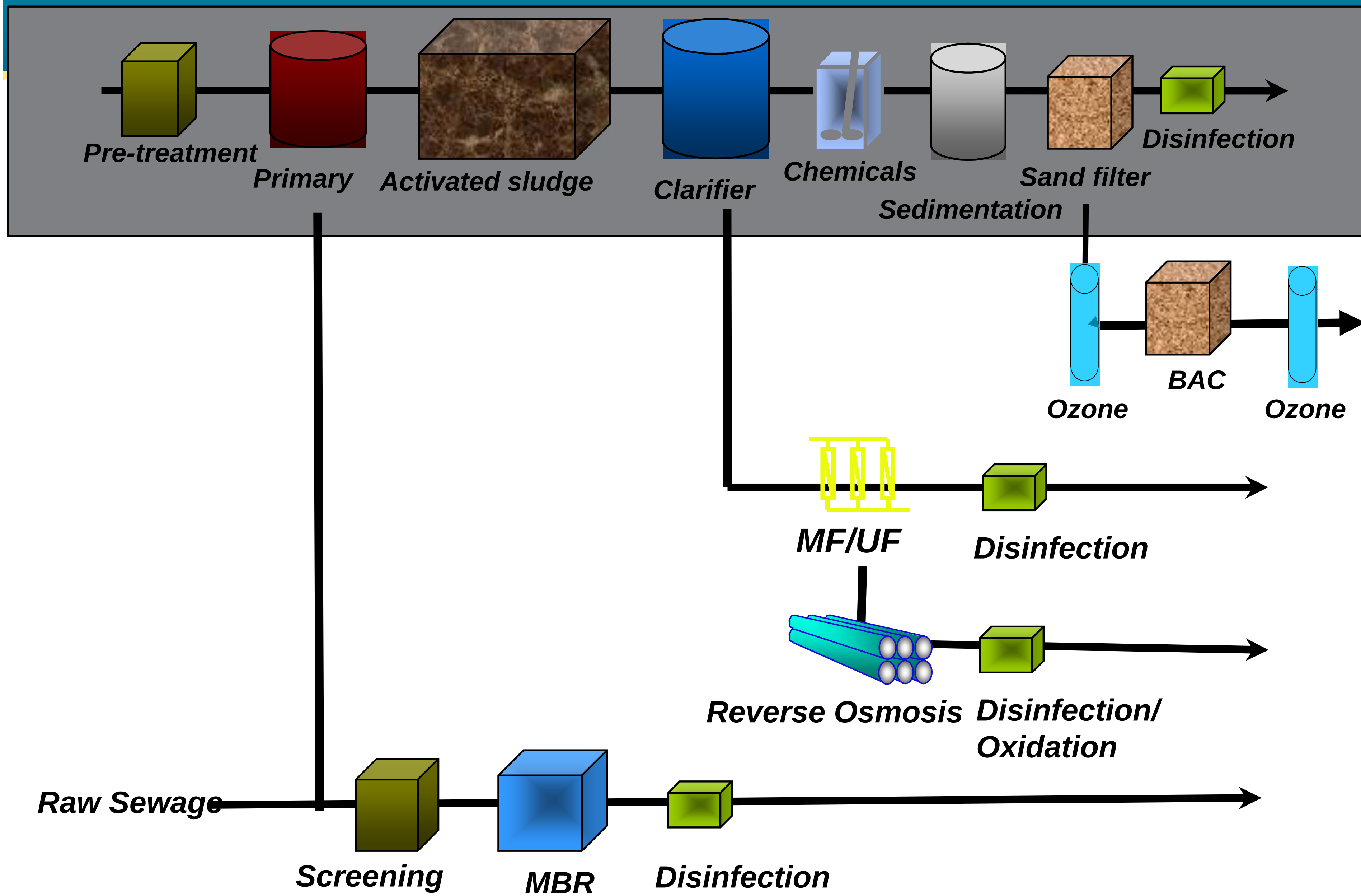
- Florida > California > Texas > Arizona

From USEPA, 2012; Jimenez and Asano, 2008; NRC, 2012.

Largest Water Reuse Programs in the US

- OCWD, CA
- Central/West Basin, CA
- MWDSC, CA
- San Jose, CA
- LACSD, CA
- San Diego County, CA
- Irvine Ranch, CA
- Dublin San Ramon, CA
- EBMUD, CA
- Orlando, FL
- Scottsdale, AZ
- Phoenix, AZ
- San Antonio, TX
- El Paso, TX
- Tarrant Regional
- St. Petersburg, FL
- Pinellas County, FL
- King County, WA
- Austin, TX
- Santa Rosa, CA
- UOSA, VA
- SNWA/LVVWD, NV

Water Reuse Treatment Trains



Regulations and Criteria

- No federal regulations
- 22 States have water reuse regulations; 11 have guidelines or design standards
- 2012 U.S. EPA Guidelines for Water Reuse
  - Recommended treatment processes
  - Water quality limits
  - Monitoring frequencies
  - Setback distances
  - Other controls

http://nepis.epa.gov/Adobe/PDF/P100FS7K.pdf; Exall, 2004; Exall et al., 2006

Reuse Applications and Number of States with Guidelines from 2004 - 2012

Type of Reuse	Number of States 2004	2012
Unrestricted Urban	28	32
Restricted Urban	34	40
Agricultural (Food Crops)	21	27
Agricultural (Non-food Crops)	40	43
Unrestricted Recreational	7	13
Restricted Recreational	9	17
Environmental (Wetlands)	3	17
Industrial	9	31
Groundwater Recharge (Nonpotable Aquifer)	5	16
Indirect Potable Reuse	5	9

http://nepis.epa.gov/Adobe/PDF/P100FS7K.pdf

Regulations and Guidelines Vary Depending on Type of Reuse

- Direct Potable Reuse
- Indirect Potable Reuse
- Agricultural Reuse on Food Crops
- Unrestricted Recreational Reuse
- Unrestricted Urban Irrigation Reuse
- Restricted Urban Irrigation Reuse
- Restricted Recreational Reuse
- Industrial Reuse
- Environmental Reuse
- Agricultural Reuse on Non-food Crops

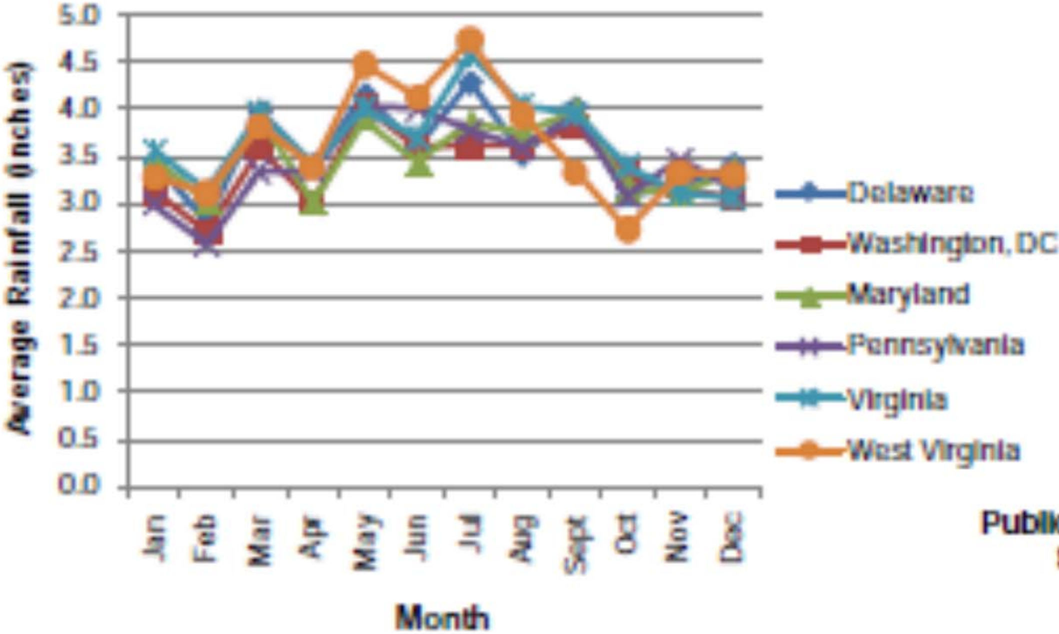
More Stringent Regulations

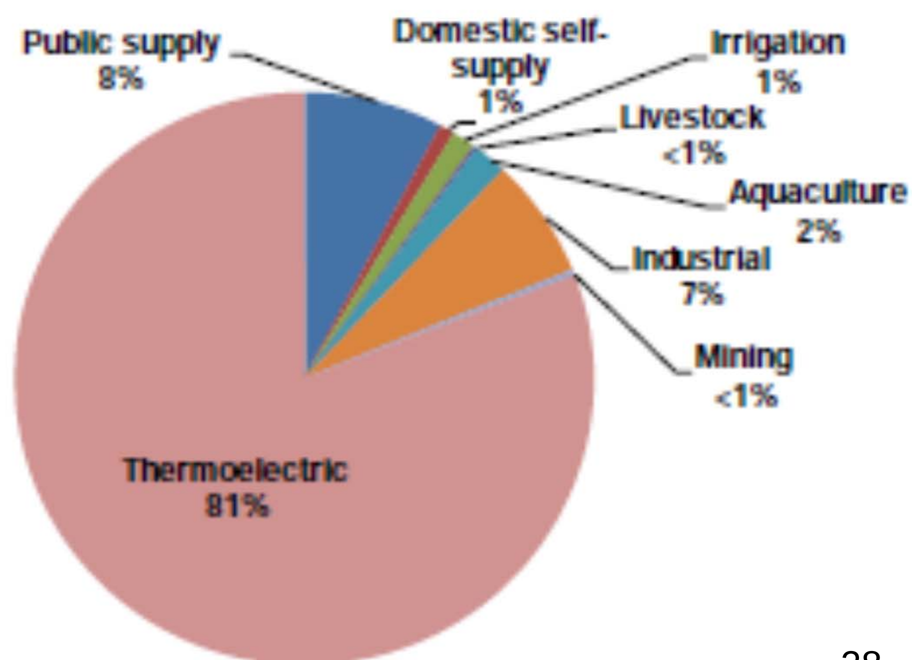
↑

Less Stringent Regulations

Adapted from Miller, 2014

Average Monthly Rainfall and Water Reuse by Sector in Mid-Atlantic Region





From USEPA, 2012.

State of MD Class IV Reclaimed Water Types

Reuse Category	Type of Reuse[a]	Related Classes[b]
Commercial, Industrial, and Government owned Facilities[c]	Aesthetic Fountains, Ponds and Lagoons; Car Washing; Closed Loop Cooling; Equipment Operation; Fire Protection; Laundering; Parts Cleaning; Pressure Cleaning; Snow Making; Toilet and Urinal Flushing[d]; and Window Washing.	None[e]
Other Industrial[c]	Aggregate Washing; Concrete Mixing; Cooling Water Systems; Dust Control and Soil Compaction; and Manufacturing Processes[f].	None[e]
Residential Outdoor Irrigation[c]	Lawns and Non-edible vegetation.	None
Non-residential Irrigation[c]	Cemeteries; Golf Courses; Highway Landscaping; Lawns; Parks; Play Grounds; School Yards; and other Green Open Spaces.	Class III
Irrigation with Restricted Access and Applicable Buffer Zone[g,h]	Fiber and Seed Crops; Food Crops Commercially Processed [i]; Forested Land; Golf Courses; Non-Food Crops; Pasture For Foraging Livestock; Silviculture; Sod Farms, Ornamental Nurseries, and Turf (including Fodder);	Classes I, II, and III

From: MARYLAND DEPARTMENT OF THE ENVIRONMENT
GUIDELINES FOR USE OF *CLASS IV* RECLAIMED WATER:
High Potential for Human Contact

MDE-WMA-002-07/15 Revised 07/2016

State of MD Reclaimed Water Standards

Parameter	Slow Rate Irrigation For Restricted Public Access		Slow Rate Irrigation for Urban Reuse-Unrestricted Public Access	Unrestricted Water Reuse (High Potential for Human Contact)
	Class I	Class II	Class III	Class IV
Biochemical Oxygen Demand (5 day) (monthly average)	70 mg/l	10 mg/l	10 mg/l	10 mg/l
Suspended Solids (monthly average for Classes I &II) or Turbidity (NTU)	90 mg/l	10 mg/l	2 NTU (daily average) Not to exceed 5 NTU at any time	2 NTU (daily average) Not to exceed 5 NTU at any time
E. coli (MPN per 100 mL) (monthly median) Or meet the Fecal Coliform limit below	N/A	N/A	N/A	1 Monthly max not to exceed 23 MPN/100ml
Fecal Coliform (MPN per 100 mL) (monthly geometric mean)	200 3 (golf course)	3	2.2	2.2 (monthly median) Monthly max not to exceed 23 MPN/100ml
pH	6.5 - 8.5	6.5 - 8.5	6.5 - 8.5	6.5 - 8.5
Total Nitrogen (monthly average)	Case by case	Case by case	Case by case	10 mg/l
Total residual chlorine at outlet of the wastewater treatment plant, wwtp)	Case by case	Case by case	Case by case	1.5-4 mg/l at outlet of WWTP 0.5-4.0 mg/l at monitoring locations in the distribution system nearby point of use

From: MARYLAND DEPARTMENT OF THE ENVIRONMENT
GUIDELINES FOR USE OF *CLASS IV* RECLAIMED WATER:
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MDE-WMA-002-07/15 Revised 07/2016

Selected and Proposed State of Maryland Reclaimed Water Projects (Class IV)

1. Little Patuxent Water Reclamation Plant – Fort Meade Federal System Reclaimed Water Project.

2. Assateague Island National Seashore WWTP effluent reuse for toilet flushing.

3. Mattawoman WWTP - Panda- Brandywine L.P. and CPV Maryland, LLC Power Plant (reclaimed water used for cooling system). Proposed reclaimed water flow about 2 mgd.

4. Piscataway WWTP – Mattawoman Power Plant (reclaimed water used for cooling system) Proposed reclaimed water flow about 5 mgd.

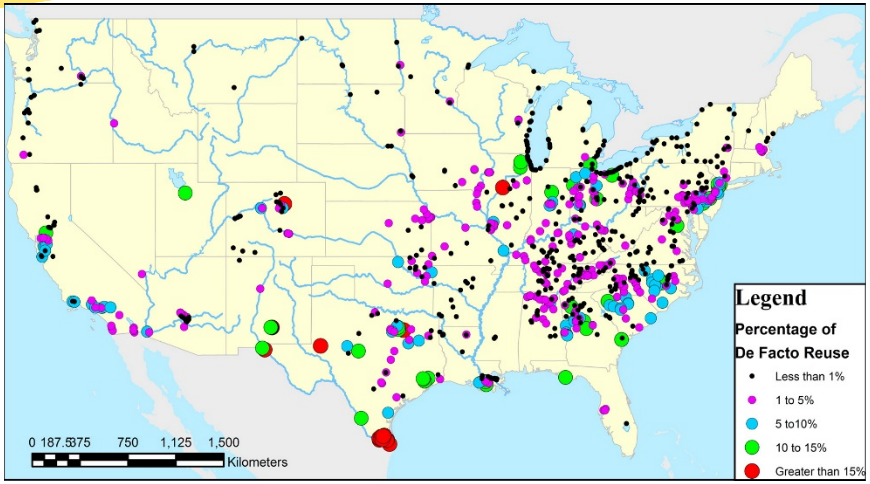
5. Smithsonian Environmental Research Center (13-DP-3562) project - use of reclaimed water for toilet flushing (100-200 gpd), lawn irrigation (15,000 gal/mo for 6 months) and fire protection (20,000 gpd storage volume).

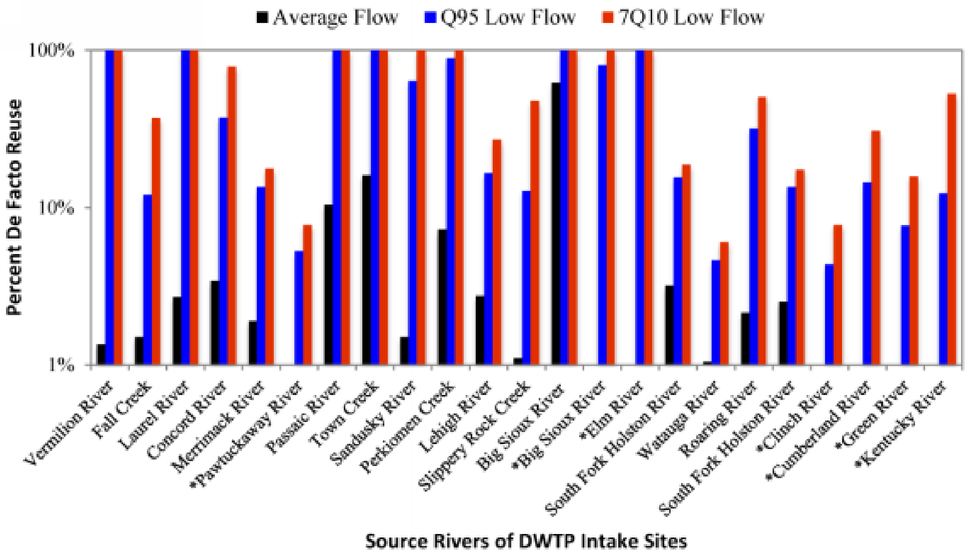
From Tien, C.T., 2015

Challenges for Water Reuse in the Chesapeake Region

- Can a water rich region actively employ the recycling of water?
- Is water recycling to be considered only when the region is under drought conditions?
- Are we ready for direct and indirect water reuse in the Chesapeake region?

UNPLANNED *(de facto)* potable water reuse



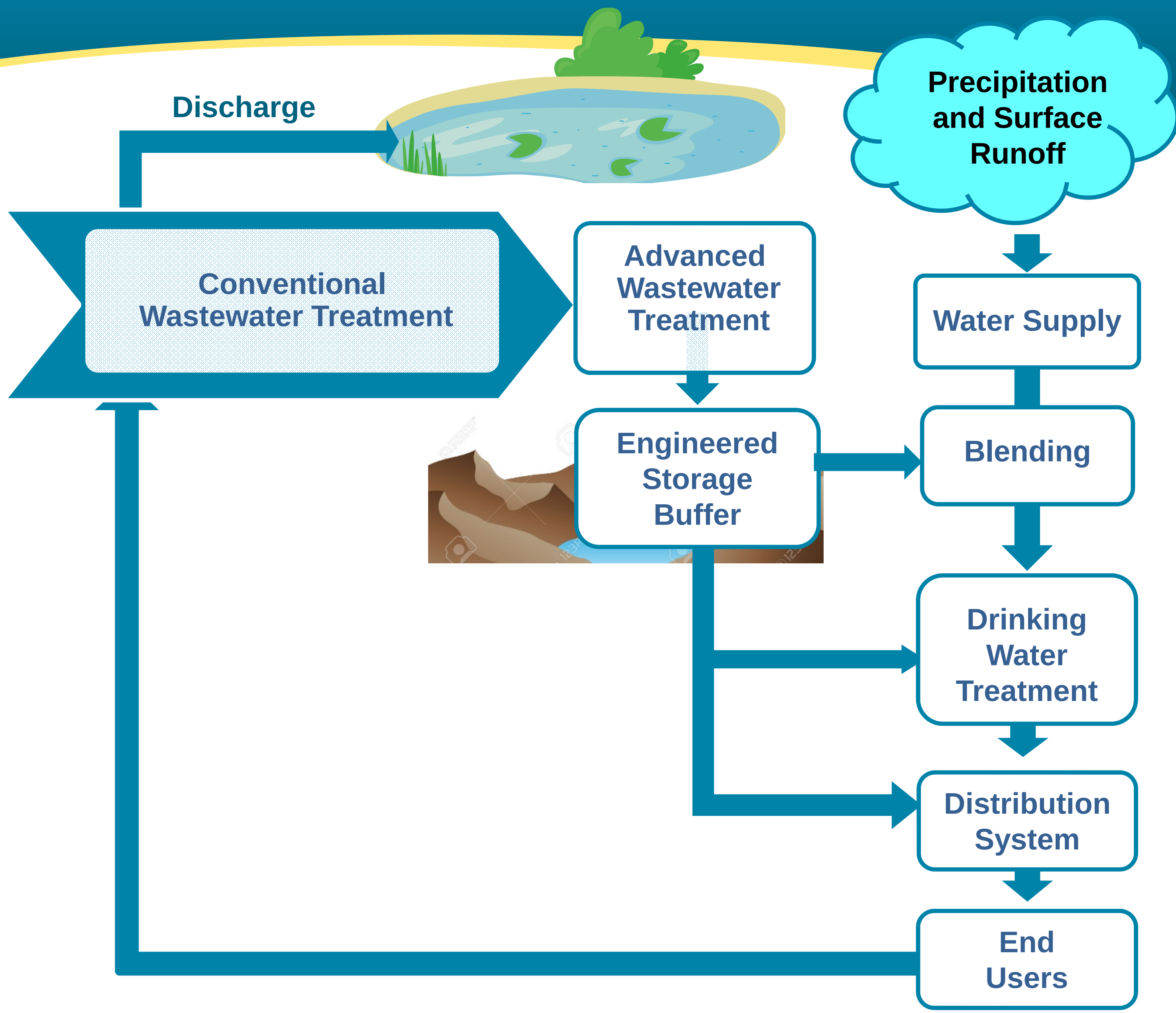


- Among 25 DWTPs studied, municipal WW flows increased by 68% from 1980 to 2008.
- De facto reuse ranged from 7 to 100% under low stream conditions.

Source: Rice and Westerhoff (2015) *ES&T* 49 (2) 982-989.

De facto reuse with 5% treated wastewater posed higher risks from wastewater contaminants than planned potable reuse schemes. (NAE, 2012)"

Indirect and Direct Potable Reuse Scenarios



Upper Occoquan Sewage Authority, Virginia
Water Reclamation Plant

The Washington Post

FRIDAY, OCTOBER 21, 2016

Hopes that wastewater can conserve land in coastal Va.

BY DARRYL FEARS

SEAFORD, VA. — It looks like a mad scientist's lab, something straight out of a sci-fi novel. Valves turn in every direction. Tubes are stacked halfway to the ceiling. Tiny bubbles dance in large vats of water.

But what's happening in a hangar of the York River Treatment Plant is real, part of a grand experiment that could help keep this coastal region from continuing to subside and eventually being claimed by the rising sea. Over the next 15 months, tests will determine whether millions of gallons of wastewater can be purified to drinking water quality and injected into the ground.

If successful, the project of the Hampton Roads Sanitation District could start to replenish a giant aquifer that thousands of industries and half a million households in the area are sucking dry. Over the past five decades, they have collectively pumped out so much water that land here is falling 4 millimeters a year — or more than 1½ inches by 2026.

Ted Henifin's jaw-dropping, eyebrow-raising idea was proposed in 2015, and last month the sanitation district general manager kicked off the pilot phase to stop what some scientists have called a nightmare in super slow motion.

Aquifers big and small exist under Hampton Roads in muddy

AQUIFER CONTINUED ON A16

From Maryland Department of Environment, 2016

Purified wastewater will be used to help restore aquifer

AQUIFER FROM A1

pockets between thick layers of earth. Pressure is relieved as water is pumped out, causing the layers, and then the land, to sink. As that geological drama played out for nearly a century, sea levels influenced by global warming crept up, to the point today where schools, homes and other property are threatened with sometimes catastrophic flooding.

Although Henifin's project still faces a multitude of regulatory challenges from the federal Environmental Protection Agency and the Justice Department, Henifin bills it as the best plan yet to rescue the aquifer and halt land subsidence.

"The project will be full scale between 2020 and 2030," he said. "It will be the biggest aquifer recharge in the country, more than 100 million gallons per day."

The unsustainable use of groundwater is often thought to be a concern only out West, where farmers in California's San Joaquin Valley have pulled so much water from aquifers since the 1920s that land has sunk by as much as 28 feet.

Yet what's happening in Norfolk, Virginia Beach, Portsmouth and the other cities that make up Hampton Roads is eerily similar. Wells are pumping about 100 million gallons of water a day out of

The lab at the York treatment plant is what Henifin calls a "pipe gallery." It hums as wastewater flows through two different processes — reverse osmosis and carbon filtering — to determine which can remove the most nutrients and unmentionable stuff more efficiently.

"I see it as a complex scientific and technical process all lined up to remove everything that can be removed from water," Henifin said.

The project boils down to punching about 30 holes about 500 feet down, deep enough to reach the level where Hampton Roads wells pump water, and injecting treated water.

Groundwater in Hampton Roads is mostly pumped from the Potomac Aquifer, the deepest part of the North Atlantic aquifer system that starts in northern North Carolina and stretches to New York's Long Island.

> *"It will be the biggest aquifer recharge in the country, more than 100 million gallons per day."*
>
> Ted Henifin, Hampton Roads Sanitation District general manager

posing to use wastewater created by all of its 1.7 million customers, the majority of whom don't use groundwater, to recharge the aquifer.

In his pitch to federal regulatory officials, Henifin stressed that purifying wastewater has benefits beyond saving the aquifer and arresting land subsidence, such as reducing the polluted sewage that enters Chesapeake Bay tributaries. He moved ahead with the pilot even without a go-ahead from EPA Region 3.

Nor does the district yet have Justice Department permission for switching how it will comply with a consent decree to reduce polluted wastewater in the bay — by cleaning shower and toilet water instead of improving underground pipes.

When two scientists at the U.S. Geological Survey learned about SWIFT, they were not convinced that the sanitation district could match the chemistry of its purified water with the land subsidence related to the aquifer.

Hydrologists Jack Eggleston and Jason Pope learned that the Hampton Roads sanitation district had the same concerns. For decades, the USGS had wanted to build a device to measure land subsidence but couldn't afford it. Eggleston and Pope discovered the Hampton Roads sanitation district would be willing to pay

Sucralose as an Indicator of Wastewater Influence

Table 3 – Compounds detected in wastewater effluents and source waters with and without municipal wastewater discharges.

Compound (MRL, ng/L)	Wastewater (ww) effluents				Sources with ww discharges			Sources without ww discharges		
	mean (ng/L)	rsd (%)	detects (%)	n	detects (%)	n	detect range (ng/L)	non detects (%)	n	detect range (ng/L)
sucralose (100)	27,000	30	100	16	100	11	120–10,000	100	15	–
diuron (5)	99	78	100	12	82	11	7.5–940	80	15	5.3–6.7
simazine (5)	21	100	100	12	73	11	24–160	20	15	7.1–61
DEET (5)	269	135	100	12	73	11	2.5–67	13	15	2.2–7.1
meprobamate (5)	323	197	100	12	70	10	5.5–160	100	15	–
caffeine (10)	127	159	75	12	64	11	13–300	100	15	–
diaminochlorotriazine (5)	36	209	67	12	64	11	13–300	40	15	10–100
TCEP (5)	547	66	92	12	60	10	7.9–66	47	15	13–64
bromacil (5)	95	100	50	12	55	11	6–270	93	15	290
sulfamethoxazole (10)	907	116	80	10	55	11	17–990	100	15	–
primidone (5)	159	49	100	12	50	8	20–54	100	15	–
2,4-D (5)	248	262	83	12	44	9	11–23	60	15	7.4–21
amoxicillin (20)	1230	92	71	7	45	11	25–2200	100	14	–
iohexal (10)	4780	120	100	16	45	11	73–960	87	15	16–39
atenolol (5)	1310	1070	100	16	45	7	6.1–200	92	13	19
carisoprodol (5)	119	156	92	12	40	10	5.4–43	100	15	–
gemfibrozil (5)	360	131	83	12	40	10	13–130	100	15	–
carbamezapine (5)	416	21	100	16	36	11	31–190	100	15	–
1,7-dimethylxanthine (5)	98	160	75	12	36	11	8.9–23	100	13	–
cotinine (10)	29	86	100	8	36	11	13–27	100	15	–
dehydronifedipine (5)	119	92	92	12	36	11	12–120	87	15	7.7–70
lopressor (20)	3900	149	67	12	36	11	22–270	100	13	–
theobromine (5)	151	158	42	12	36	11	6.4–41	67	15	7.8–25

From Oppenheimer, Eaton, Badruzzaman, Haghani and Jacangelo, *Water Research* 45:4019-4027 (2011)

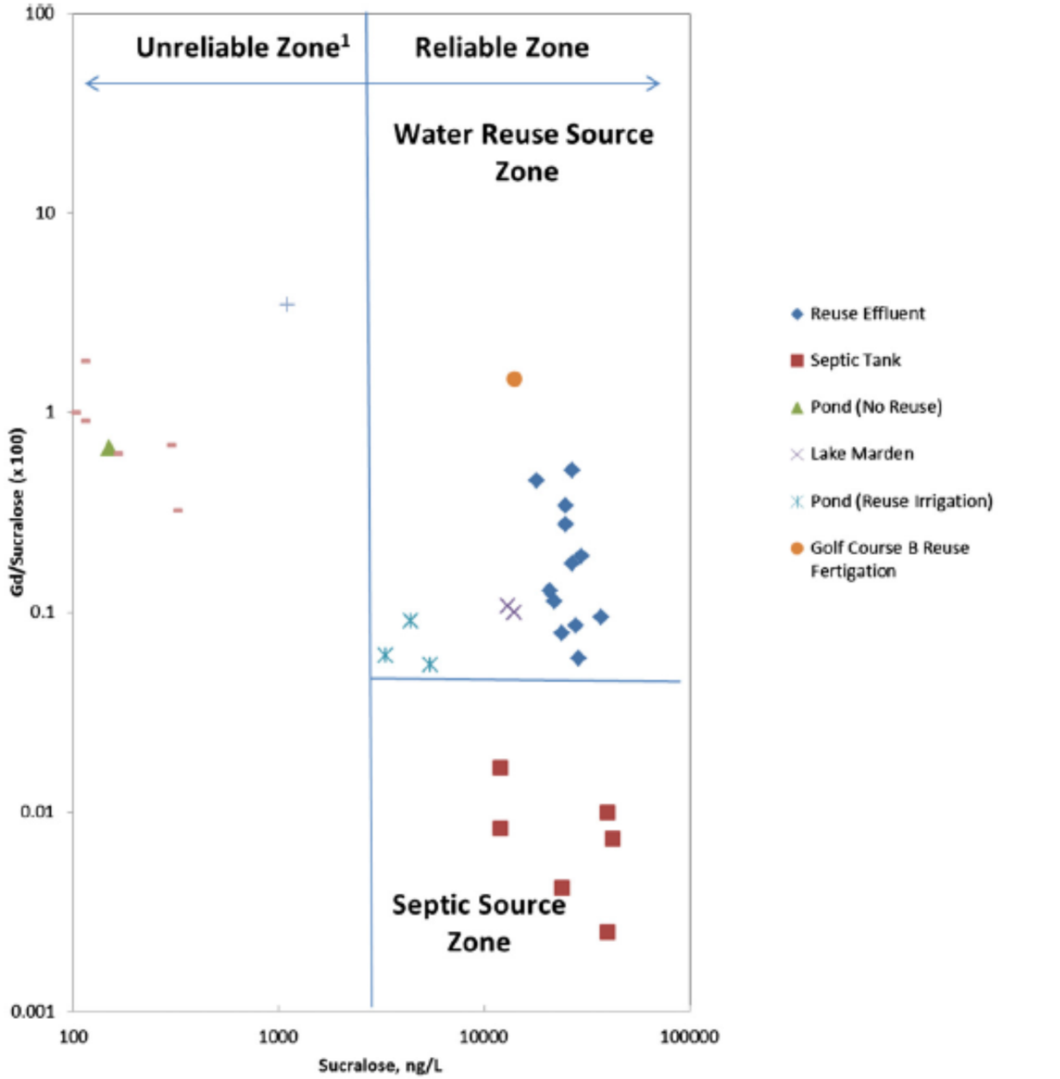
Sucralose Detected In Septic Systems

Table 4 – Comparison of sucralose and carbamazepine concentrations in single grab samples collected from eight septic systems located in two separate counties in Florida.

	Sucralose (ng/L)	Carbamazepine (ng/L)
septic 1	69,000	<5
septic 2	40,000	40
septic 3	80,000	<5
septic 4	42,000	<5
septic 5	24,000	55
septic 6	40,000	<5
septic 7	12,000	<5
septic 8	12,000	<5

From Oppenheimer, Badruzzaman and Jacangelo, *Water Research* 46:5904-5916 (2012)

Use of gadolinium to sucralose ratios for detecting source of nutrient loading



[1]Unreliable zone is the region where sucralose is <3,000 ng/L and the Gd anomaly concentrations are too low to provide a meaningful ratio.

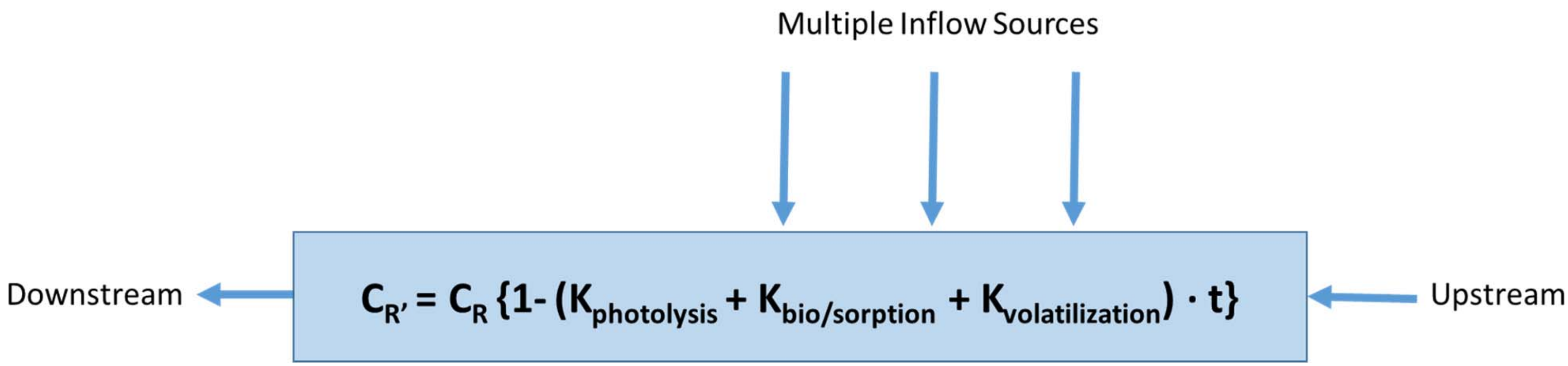
Fig. 3 – Gd anomaly/sucralose ratio for various locations.

From Oppenheimer, Badruzzaman and Jacangelo
Water Research 46:5904-5916 (2012)

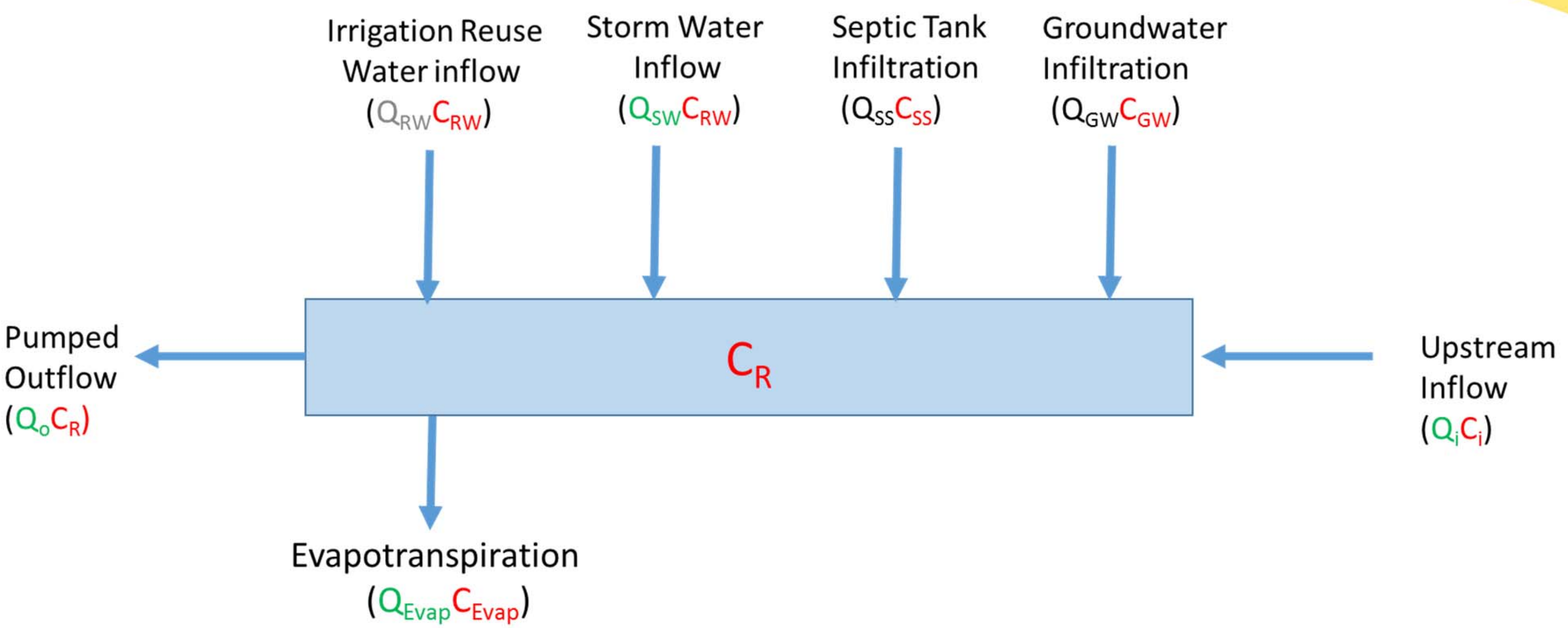
Use of Iohexal as a Marker for Nutrients

- Found in reclaimed water at effluent from plant and streams when loading occurs
- Not impacted by chlorination
- Not readily found in septic
- Not readily found in rainwater
- Not reaily found in groundwater

Water Body Marker Attenuation

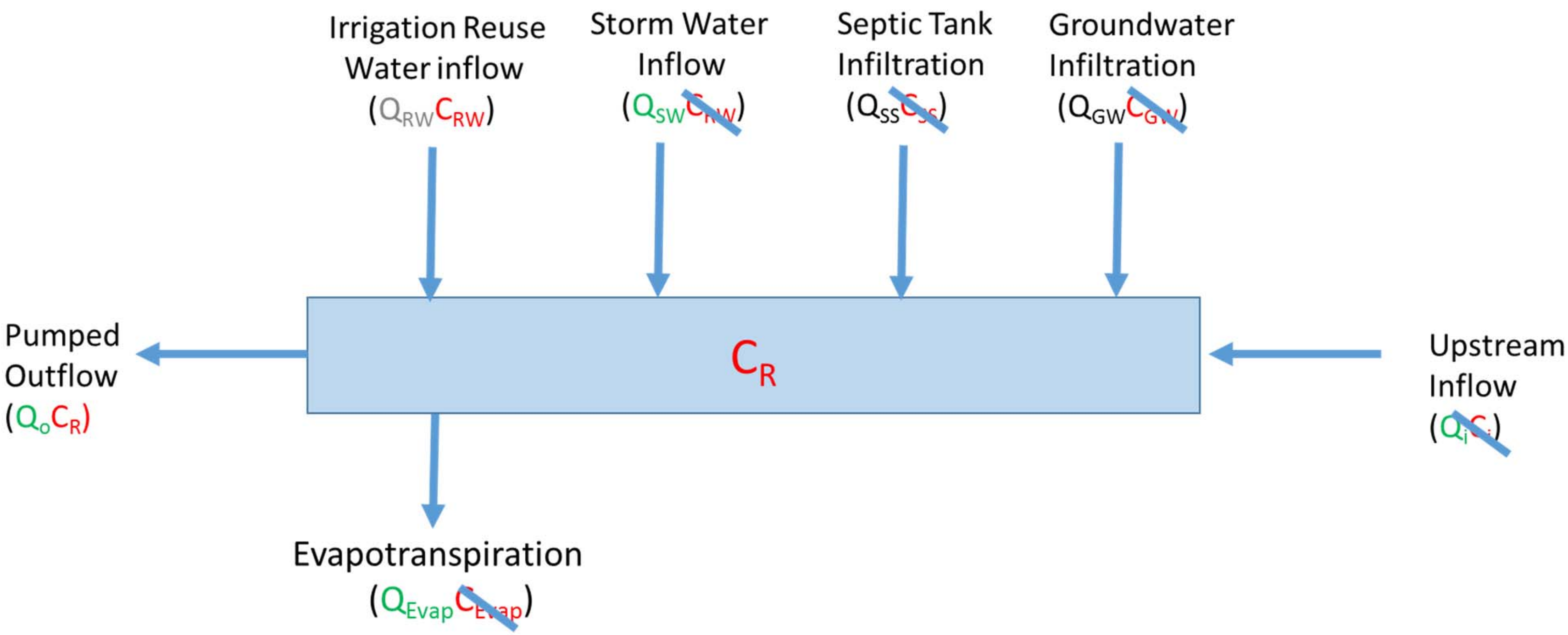


Nutrient Loading to River from Sources



$$C_R = \{[Q_iC_i + Q_{GW}C_{GW} + Q_{SS}C_{SS} + Q_{SW}C_{SW} + Q_{RW}C_{RW} - Q_oC_R - QE_{vap}C_{Evap}] / [Q_I + Q_{GW} + Q_{SS} + Q_{SW} + Q_{RW} - Q_o - Q_{Evap}]\}$$

Marker Loading to River from Sources



$$C_R = \{[\cancel{Q_iC_i} + \cancel{Q_{GW}C_{GW}} + \cancel{Q_{SS}C_{SS}} + \cancel{Q_{SW}C_{SW}} + Q_{RW}C_{RW} - Q_oC_R - \cancel{Q_{Evap}C_{Evap}}] / [Q_i + Q_{GW} + Q_{SS} + Q_{SW} + Q_{RW} - Q_o - Q_{Evap}]\}$$

Load Fraction from Reuse Source

- $$C_R = \frac{Q_{RW}C_{RW} - Q_o C_R}{Q_i + Q_{GW} + Q_{SS} + Q_{SW} + Q_{RW} - Q_o - Q_{Evap}}$$

- $$Q_{RW} = \frac{C_R}{C_R - C_{RW}}\left(Q_{Evap} - Q_i - Q_{GW} - Q_{SS} - Q_{SW}\right)$$

- $\frac{C_R}{C_R - C_{RW}}$ is the fractional flow of reuse to total flow

Example Calculation of Reuse Loading

If kt = 0.90

$C_{R'}$ = 50 ng/l

C_{RW} = 5,000 ng/l

$\frac{C_R}{C_R - C_{RW}}$ = 11.1% reuse contribution to total flow

If kt = 0.70

$C_{R'}$ = 50 ng/l

C_{RW} = 10,000 ng/l

$\frac{C_R}{C_R - C_{RW}}$ = 1.7% reuse contribution to total flow

If kt = 0.70

$C_{R'}$ = 50 ng/l

C_{RW} = 5,000 ng/l

$\frac{C_R}{C_R - C_{RW}}$ = 3.45% reuse contribution to total flow

Summary

- It's not wastewater.
- Used water has value!!
- Look at water not just as a liquid stream from the faucet, but as an embedded resource (virtual water) in every aspect of our lives.
- Will with the Chesapeake region become a major reuse area of the country?????

Thank You

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Planned Potable Reuse