



THE
**Water
Research**
FOUNDATION

Webcast

Validation Protocols for Membrane Bioreactors and Ozone/Biologically Activated Carbon for Potable Reuse Project 4997

October 15, 2020



Housekeeping Items

- Submit questions through the question box at any time. We will do a Q&A near the end of the webcast.
- Slides and a recording of the webcast will be available at www.waterrf.org.
- A certificate of completion will be generated after the webcast. Any questions, please contact msuazo@waterrf.org.
- Survey at the end of the webcast.

Project Team



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Amos Branch -
Carollo Engineers



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Project Advisory Committee

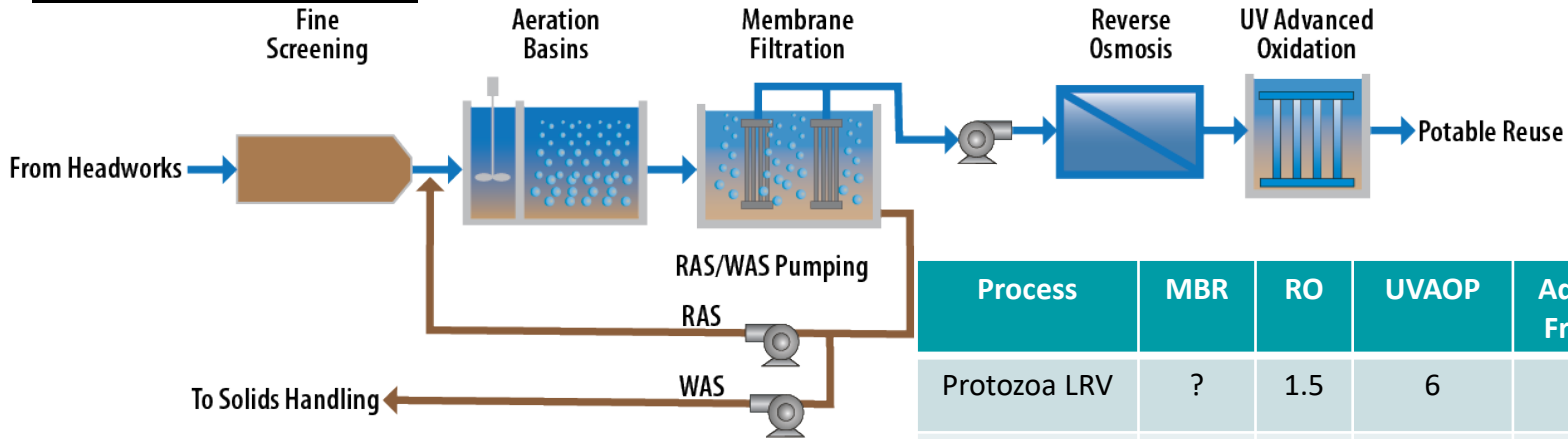
Brian Bernados –
CA Division of Drinking Water,
Charles Bott –
Hampton Roads Sanitation District,
and
Cedric Robillot –
Head Start Development

Ozone/Biologically Activated Carbon

- Developed literature review for Ozone/BAC LRVs
 - Published as part of final report and includes grey literature and unpublished utility data
- Created Roadmap for Ozone/BAC Validation Protocol
 - Phase 1: Develop validation approach: baseline to complex
 - Identify mechanisms of removal, define design criteria, define critical operating parameters, identifying target pathogens, identify byproducts, identify data gaps, develop protocol
 - Phase 2: Develop tiered validation protocol
 - Tier 0: baseline LRV, based on known ozone performance
 - Tier 1: set-point monitoring for conservative performance
 - Tier 2: data-driven, multi-monitoring, dynamic approach

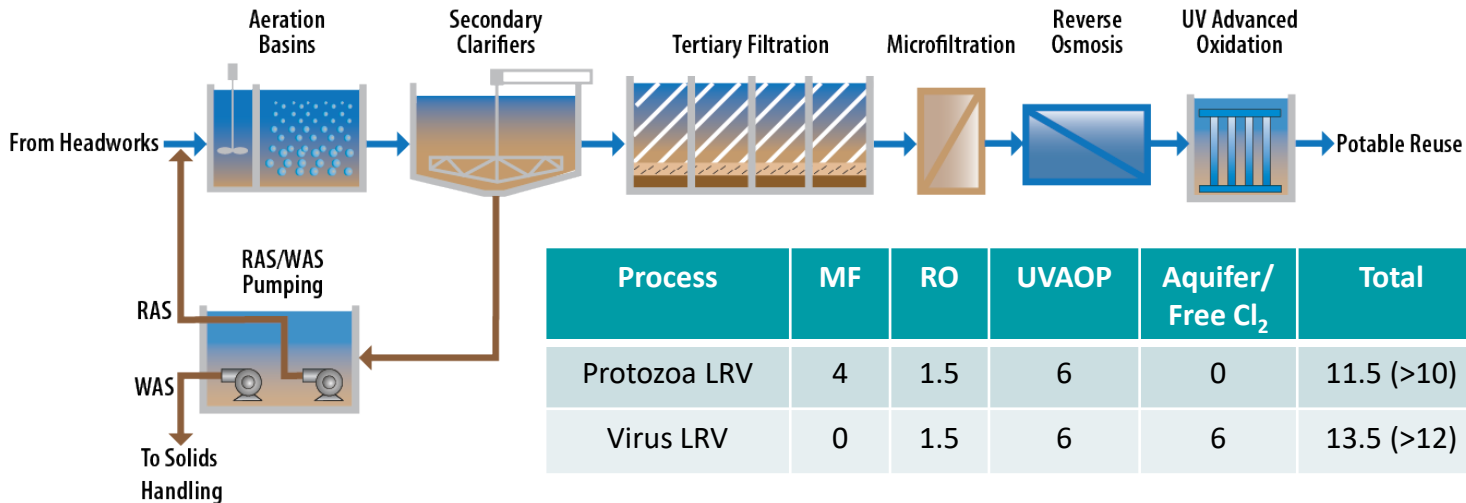
Challenges for MBR Potable Reuse

MBR Reuse Scheme



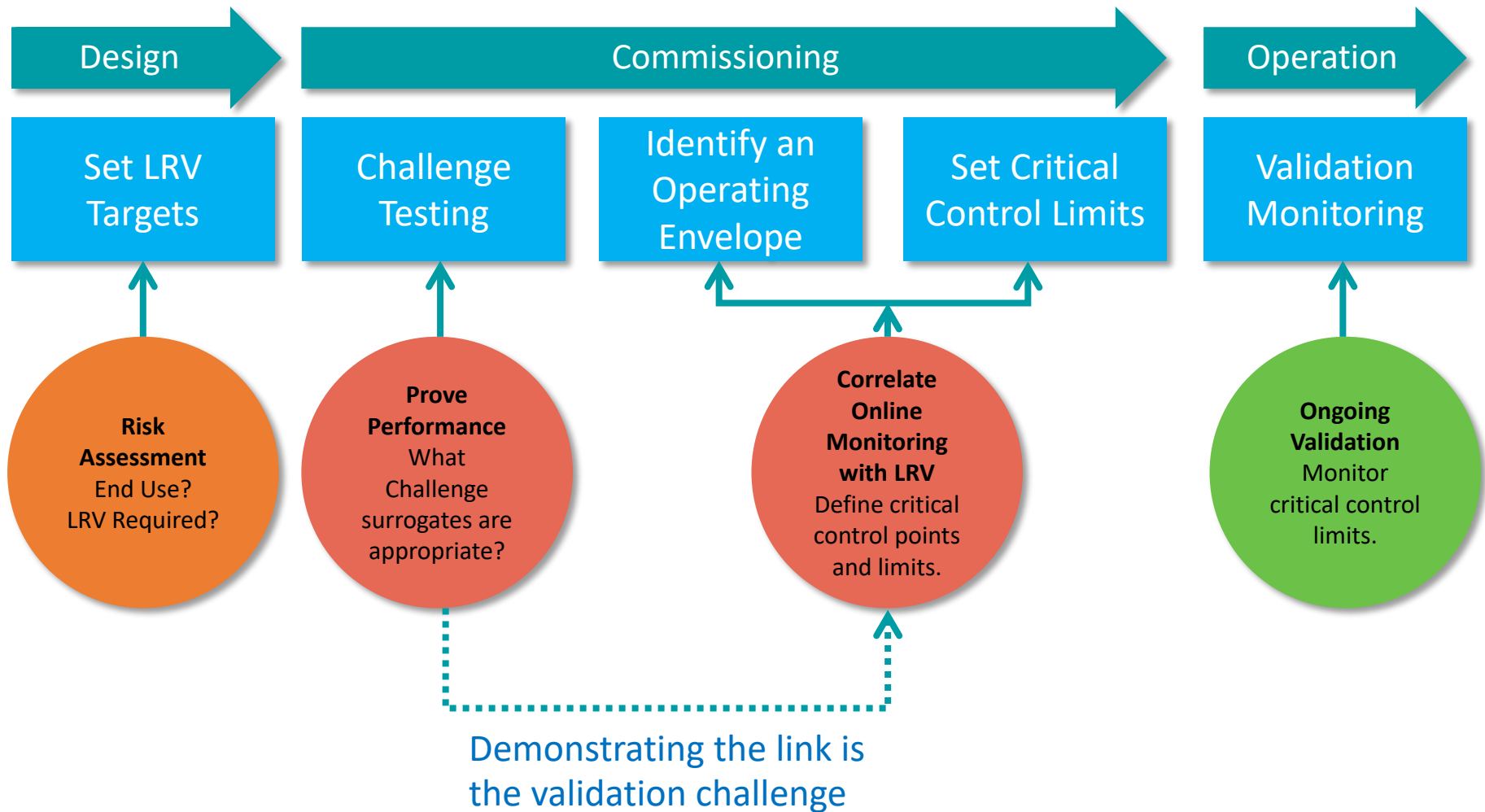
Process	MBR	RO	UVAOP	Aquifer/ Free Cl ₂	Need
Protozoa LRV	?	1.5	6	0	+2.5
Virus LRV	?	1.5	6	6	0

Conventional Full Advanced Treatment

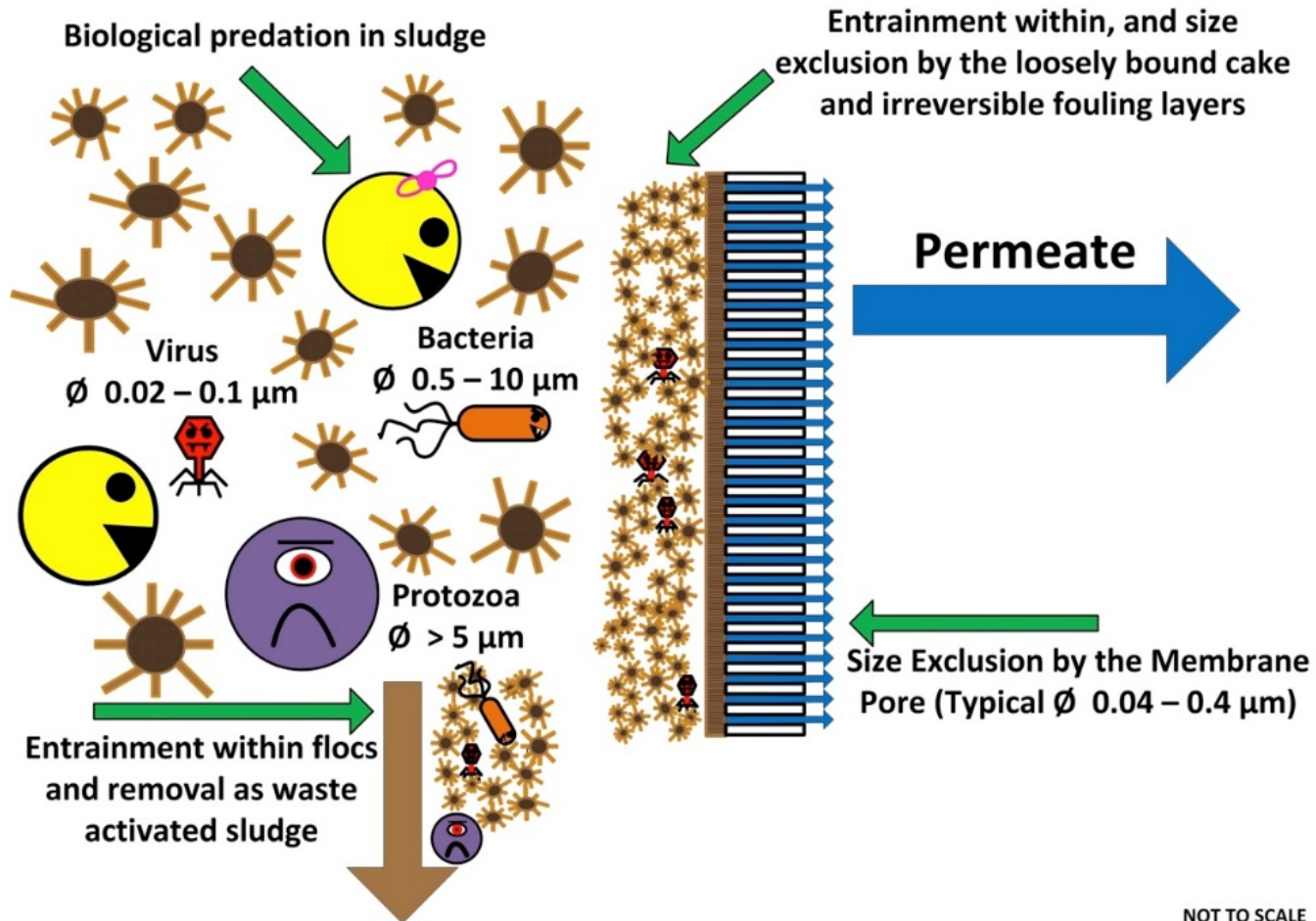


Process	MF	RO	UVAOP	Aquifer/ Free Cl ₂	Total
Protozoa LRV	4	1.5	6	0	11.5 (>10)
Virus LRV	0	1.5	6	6	13.5 (>12)

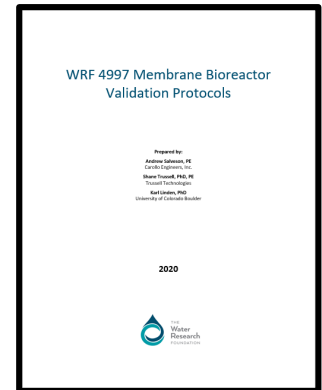
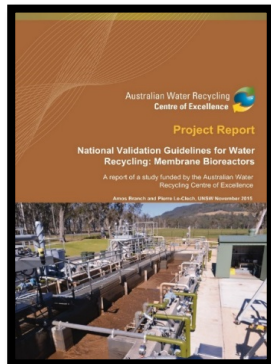
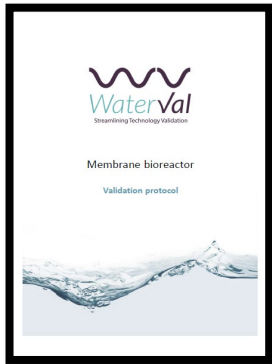
Treatment Process Validation



MBRs are Complex and Remove Pathogens in a Number of Ways



Project Goals

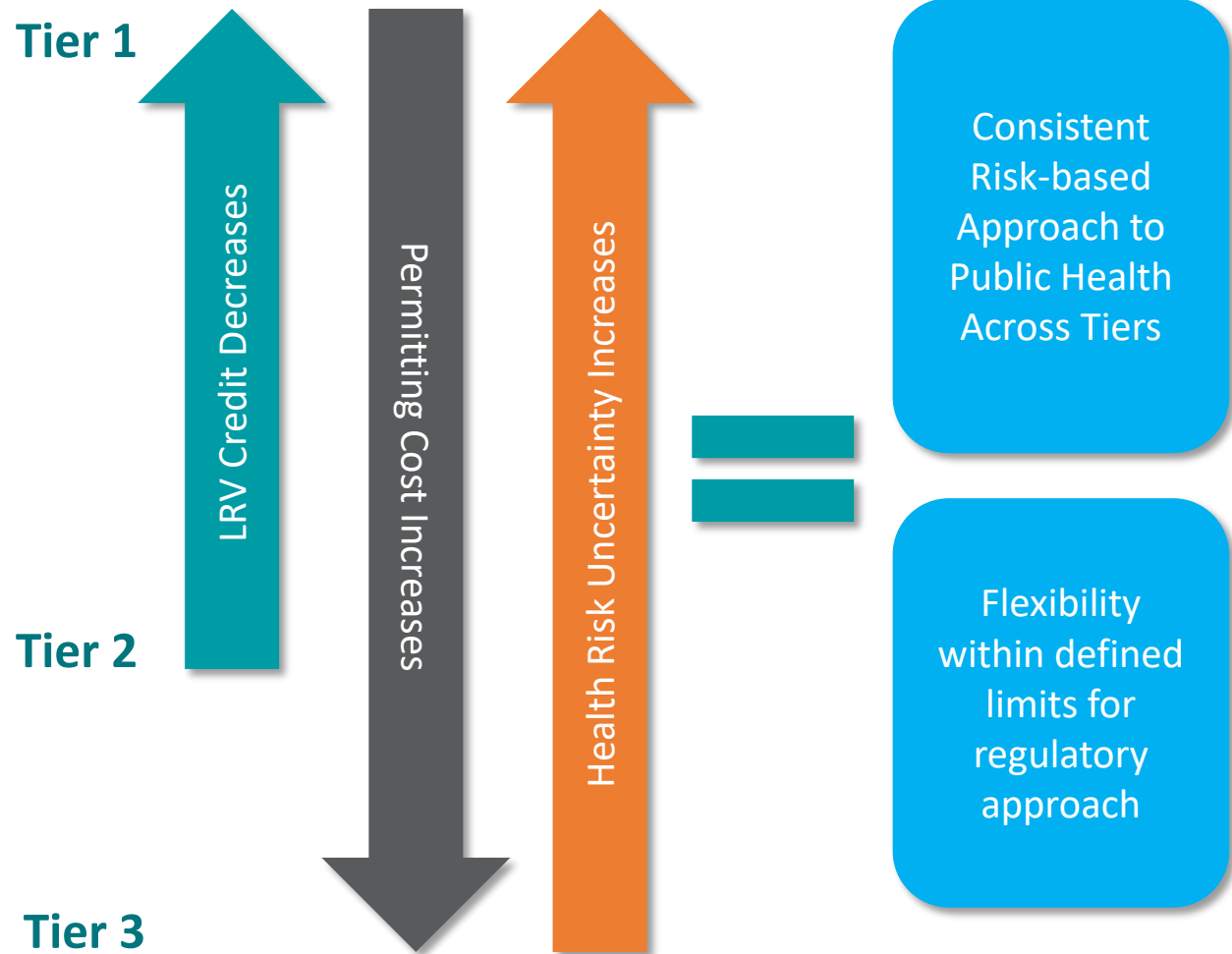


Project Goals

- Conduct a broad literature review of pathogen data from pilot and demonstration scale systems using MBRs for potable reuse or other similar applications and conclude upon conservative minimum LRVs for virus and protozoa. Document a performance surrogate (e.g., turbidity) that can be used to verify the LRVs.
- Develop a U.S.-based MBR Validation Protocol for Tier 2 that includes verifying the approach for applying default LRV values and monitoring requirements

Tiered MBR Concept

- Better demonstration may lead to higher credits
- Does not preclude low risk schemes as a conservative option

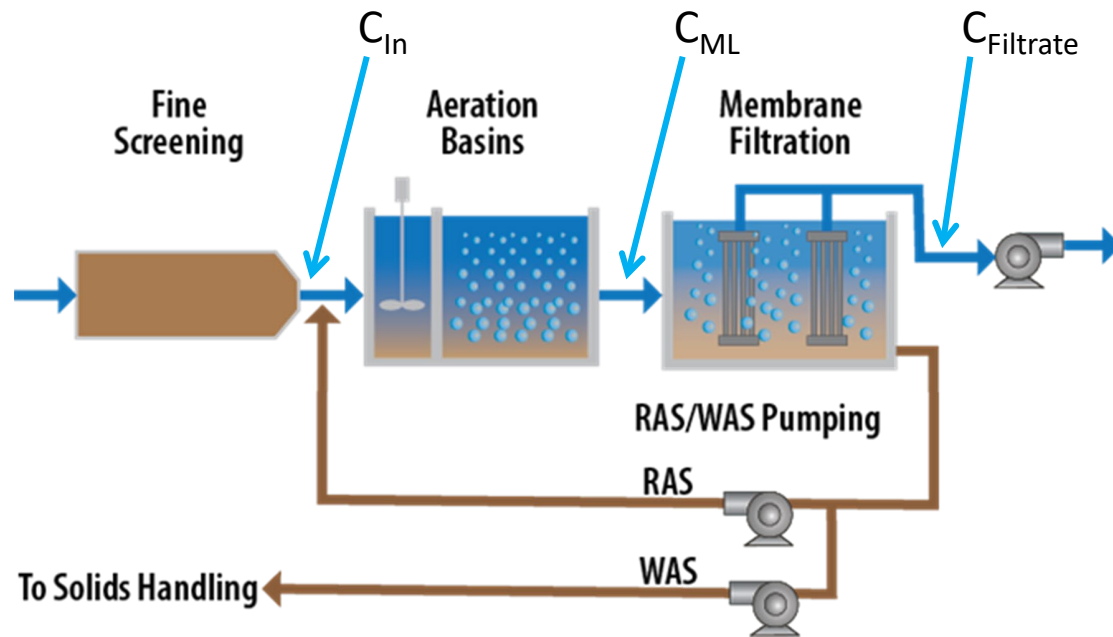


WRF Tier 1 Objectives

- Updated review of current knowledge of MBR validation of relevance to the U.S.
- Re-examination of the relationship between MBR LRV and turbidity from Australian and U.S. Studies
- Assessment of most probable worst case LRV from updated data

WaterVal Data

- 11 full-scale sites sampled, over 180 site visits
- Multiple indicator organisms analyzed
 - Viruses – Somatic and male-specific coliphage
 - Bacteria – *E. coli* and *Total Coliforms*
 - Protozoa – *Clostridium Perfringens*
- Trends in performance analyzed



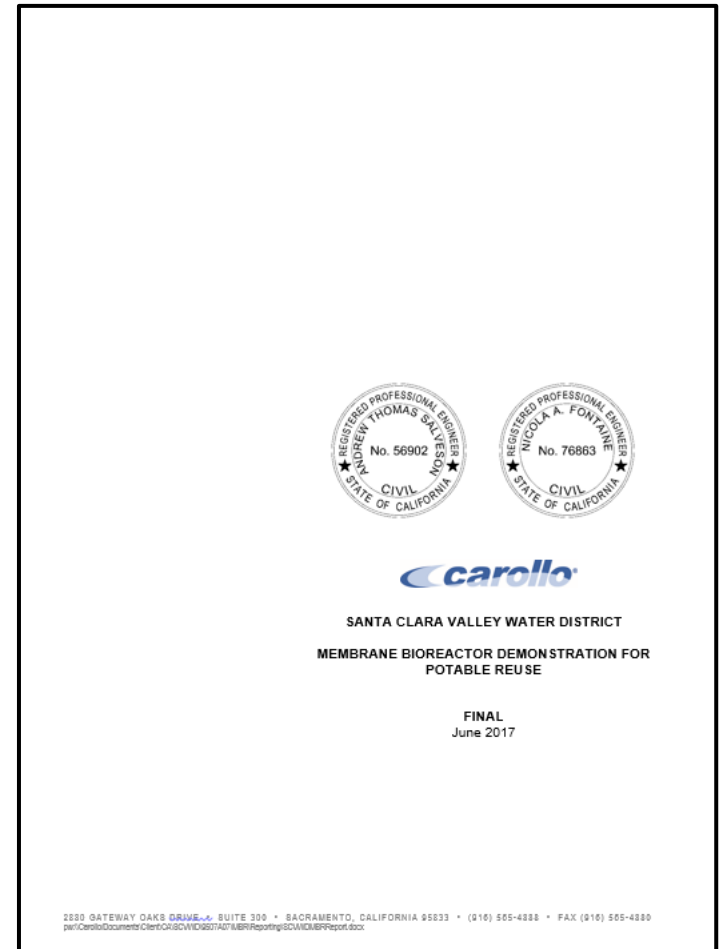
$$LRV_{MBR} = \log_{10} \left| \frac{C_{In}}{C_{Filtrate}} \right|$$

$$=$$

$$\left(LRV_{Bio} = \log_{10} \left| \frac{C_{In}}{C_{ML}} \right| \right) + \left(LRV_{Mem} = \log_{10} \left| \frac{C_{ML}}{C_{Filtrate}} \right| \right)$$

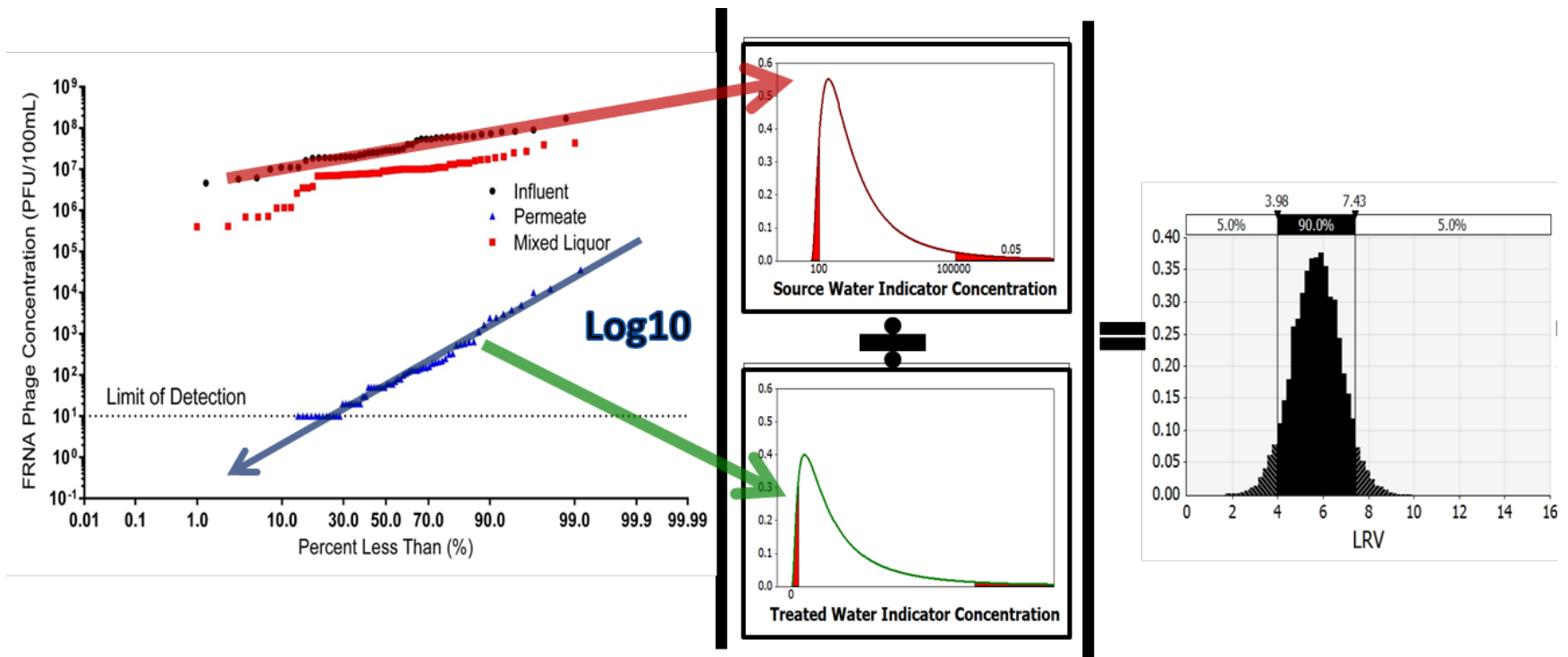
Valley Water MBR Study (2017)

- New data from California
 - Normal operation
 - 2 x Full Scale DuPont
 - 2 x Full Scale Suez
 - 1 x Pilot Scale Suez
- Indicators and Pathogens
 - + 40 *Cryptosporidium* and *Giardia* LRVs
 - Same virus and protozoa indicators as NatVal



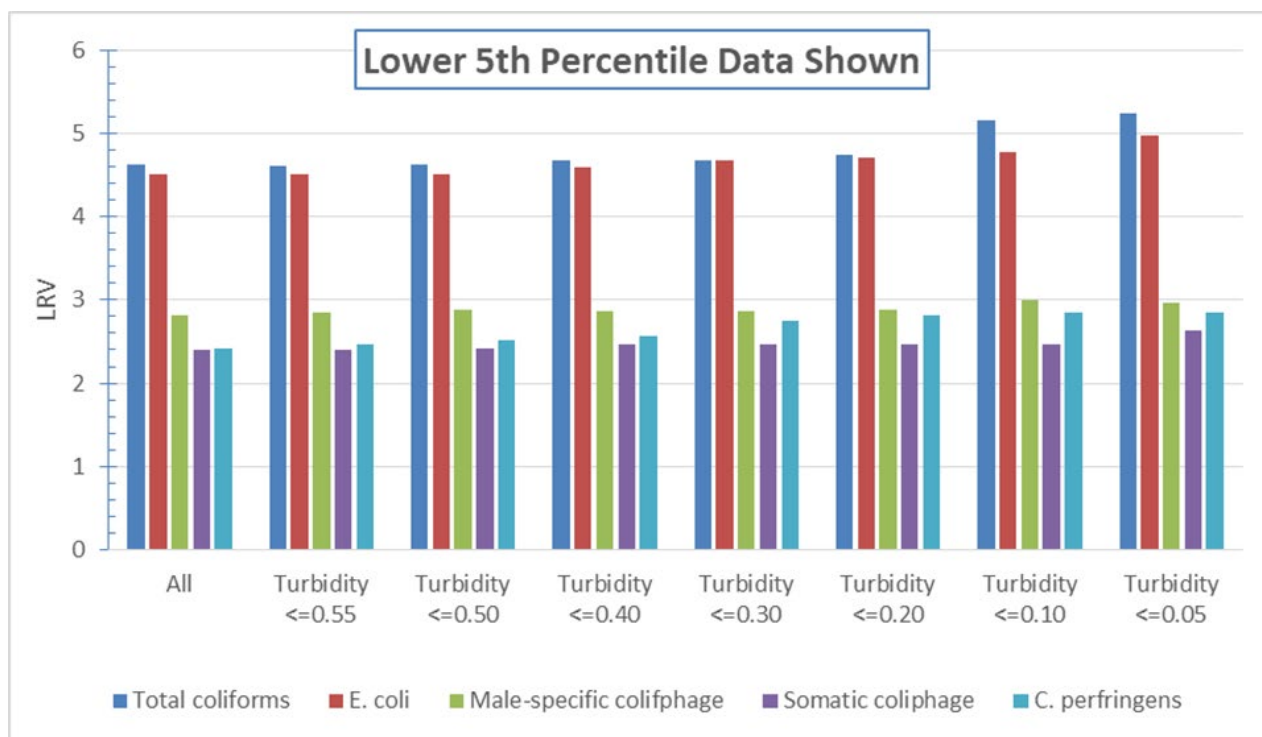
Data Analysis

- Compare probabilistic and paired LRV calculation (WaterVal and Valley Water).
- Re-analyze WaterVal data and relate to turbidity.



Tier 1 Filtrate Turbidity Criteria

- 5th Percentile LRVs re-examined in different operating turbidity ranges from < 0.2 NTU up to the maximum limit of 0.5 NTU in California
- Conclusion: at Less than 0.5 NTU, MBR should achieve Virus, Bacteria and Protozoa LRV of 2.4, 4.5 and 2.5, respectively.



Tier 1 – Paired vs Monte Carlo LRV Calculation

- Conclusion: Virus LRV as low as 1.0 is possible based on Somatic Coliphage, and Protozoa LRV of 2.5 is conservative based on *Clostridium perfringens*

Pathogens and Indicators		Branch and Le-Clech 2015					SCVWD 2017				
		No. of samples	No. of ND in Filtrate	Range of LOD	5th Percentile LRV		No. of samples	No. of ND in Filtrate	Range of LOD	5th Percentile LRV	
					Paired data	Monte Carlo				Paired data	Monte Carlo
Virus	Male-specific coliphage (pfu/100 mL)	184	150	1 - 10	2.8	2.9	35	20	1	2.6	2.3
	Somatic coliphage (pfu/100 mL)	202	55	1 - 10	2.5	1.9	34	0	1	1.5	1.0
	Norovirus GIA (GC/L)						11	5	0.04 - 0.4	4.0	3.0
	Norovirus GIB (GC/L)						11	6	0.04 - 0.4	3.3	3.3
	Norovirus GII (GC/L)						12	7	0.04 - 0.4	4.8	4.4
	Total culturable virus (MPN/L)						12	5	0.015 - 0.02	2.3	1.6
	Enterovirus (MPN/L)						10	5	0.04 - 0.4	4.2	2.9
Bacteria	C. perfringens (cfu/100 mL)	227	172	1	2.8	3.5					
	E. coli (cfu/100 mL)	227	103	1	4.7	5.1					
	Total coliforms (cfu/100 mL)	186	4	1	4.7	4.8					
	Enterococci (cfu/100 mL)						29	6	1	4.1	3.9
Protozoa	Cryptosporidium (oocysts/L)						39	39	0.004 - 1	1.3	1.5
	Giardia (cysts/L)						43	25	0.004 - 1	3.4	3.6

Tier 1 Take Away

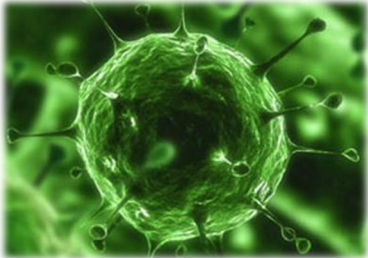
- Turbidity appears to increase in line with more frequent occurrence of lower LRVs
- A Turbidity criteria of 0.2 NTU, as regulated in California, is conservative and appropriate for Tier 1.
- A holistic assessment of both Australian and new US data concludes Tier 1 LRVs of:
 - 1.0 for Virus,
 - 2.5 for Protozoa
 - Subject to the above turbidity criteria.

Tier 2 MBR Validation Protocol



Tier 2 - Target Pathogens and Indicators

Virus

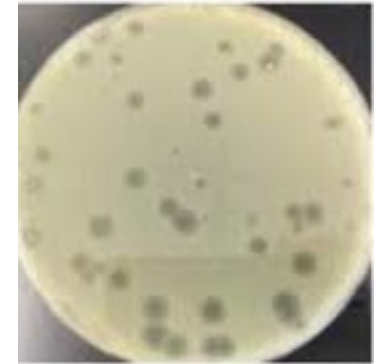


Cryptosporidium

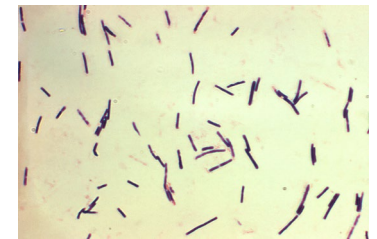


Pathogen Group	Target Organism	Indicator Organisms
Viruses	Enteroviruses	Somatic and Male-specific coliphages
Protozoa	<i>Cryptosporidium</i>	<i>Clostridium Perfringens</i>

Coliphage



C. Perfringens



Phases for Tier 2 Validation

Pre-Commissioning

Demonstrate product specific pathogen removal and surrogates

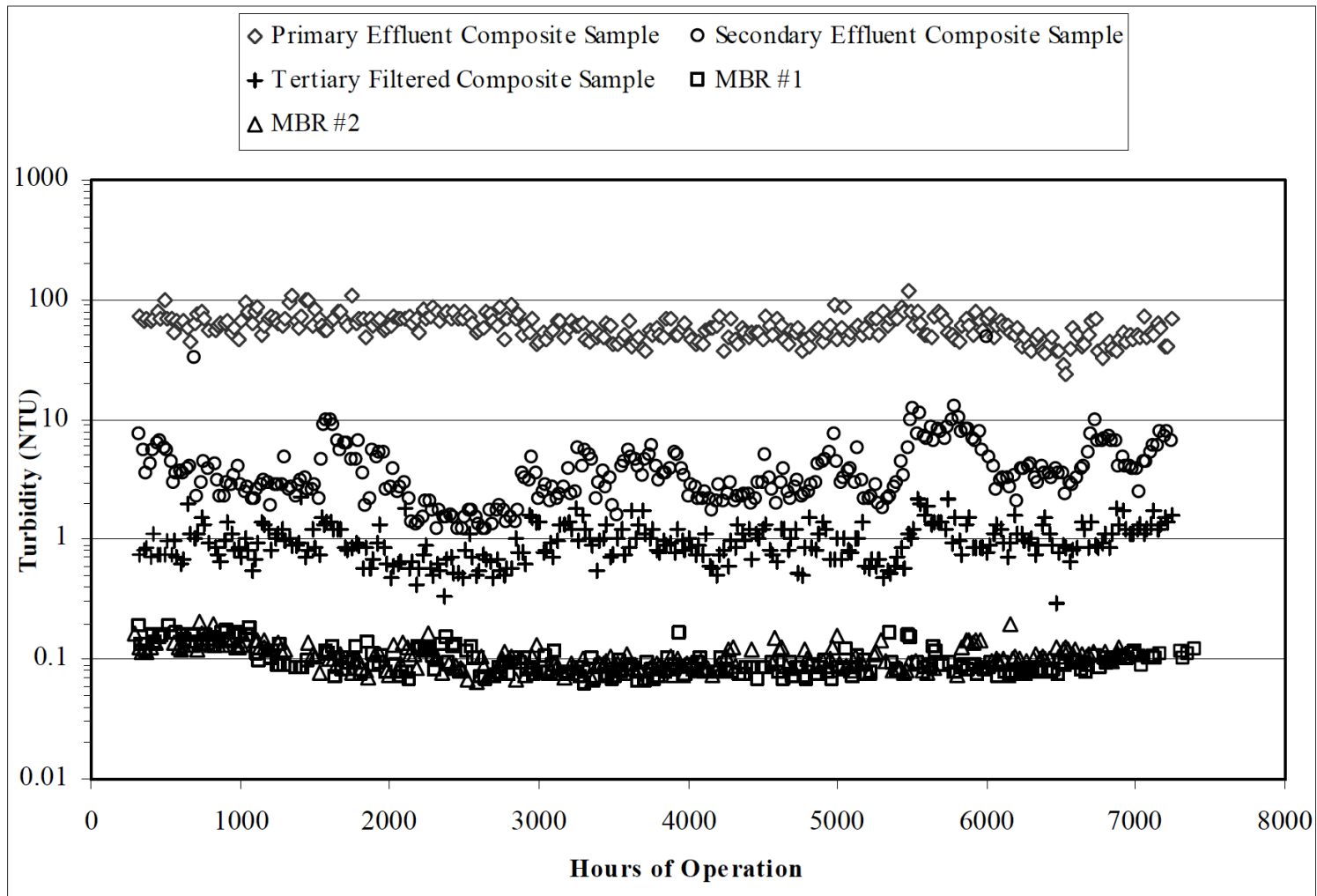
Commissioning

Year 1 sampling to demonstrate pathogen removal and surrogates

On-Going Sampling

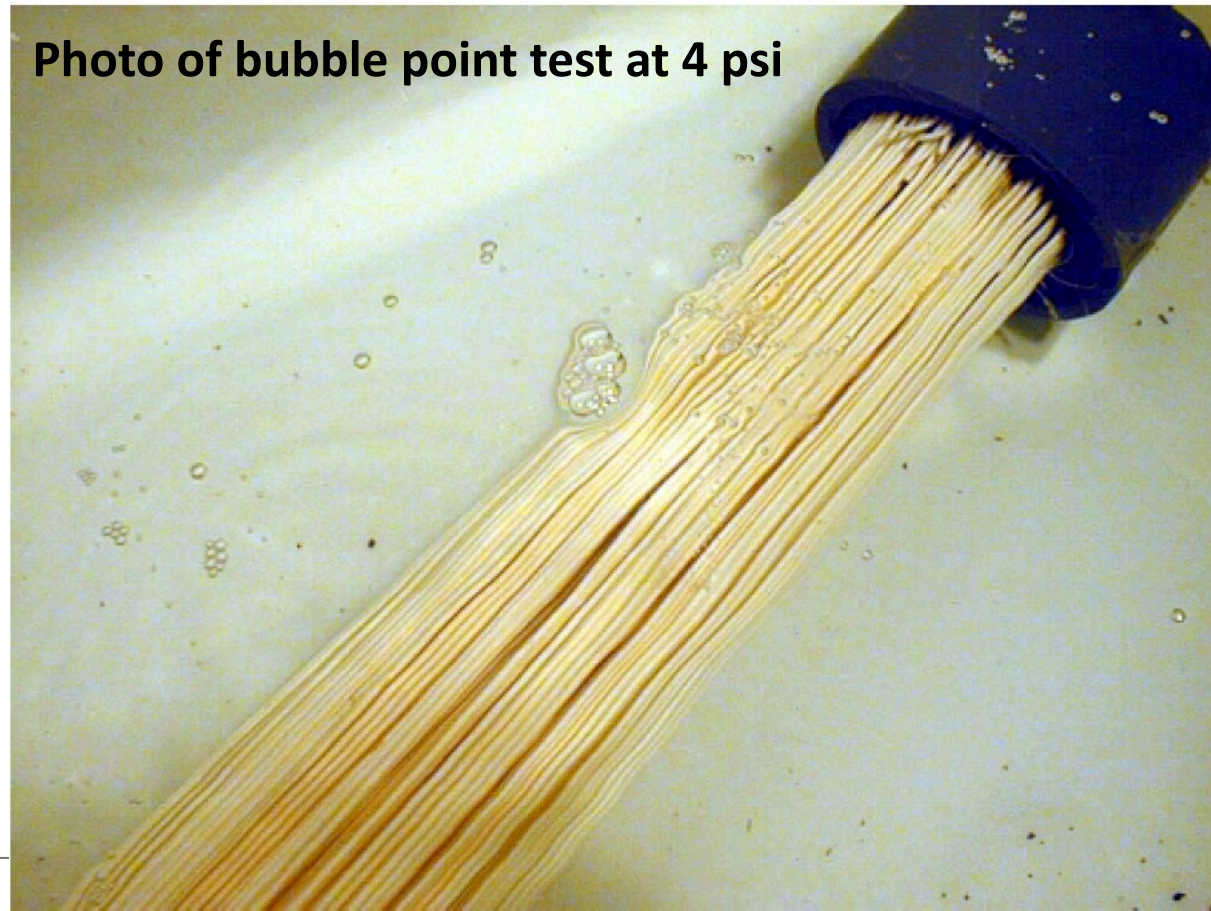
Monthly samples can be reduced to quarterly

Surrogate #1 - Turbidity

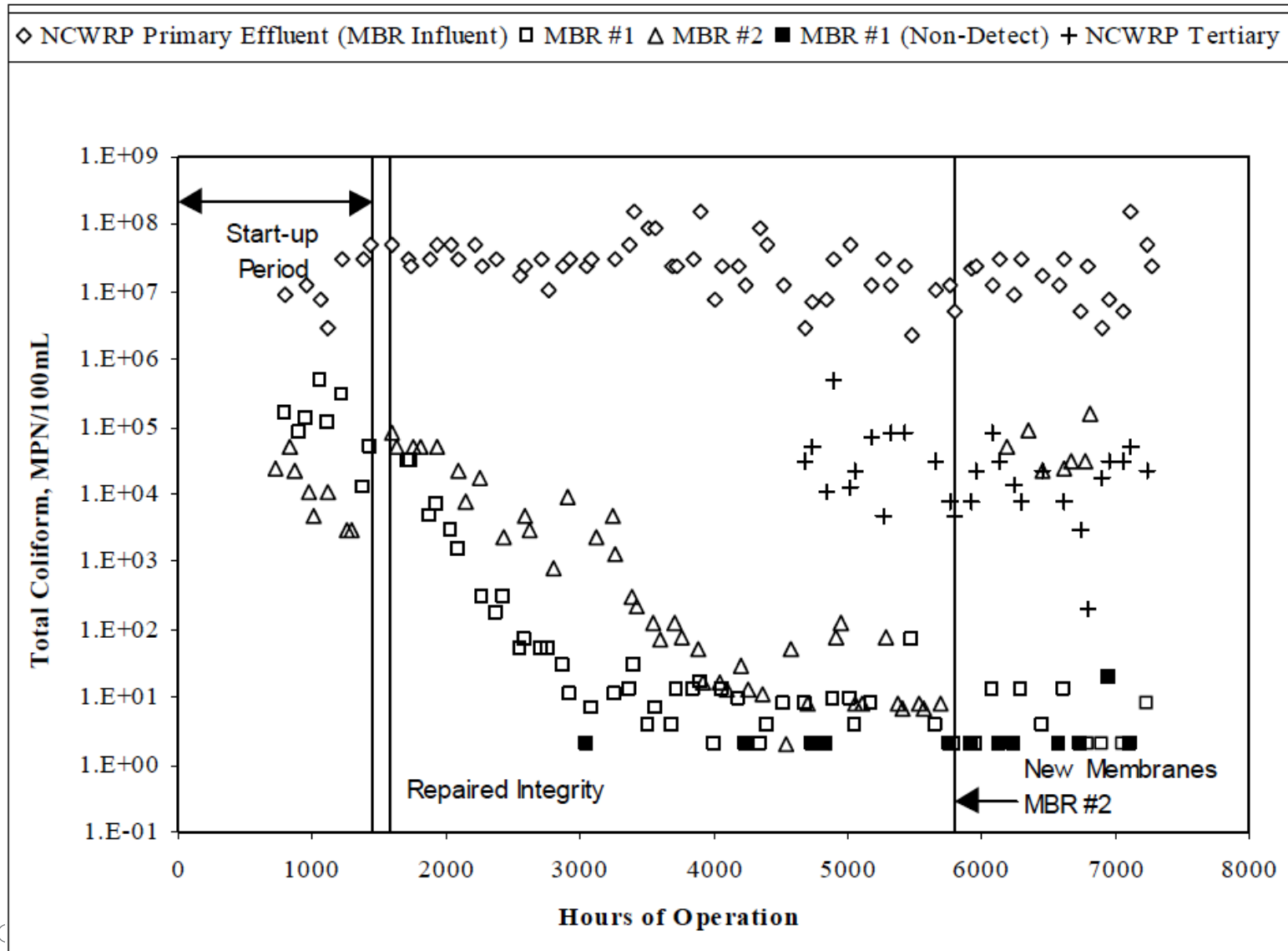


Surrogate #2 – Pressure Decay Test

- Pressures needed for USEPA membrane filtration guidance manual are not required, but are acceptable
- Requirement is that PDT must correlate or provide an established limit related to pathogen LRV, not achieve 3 um resolution

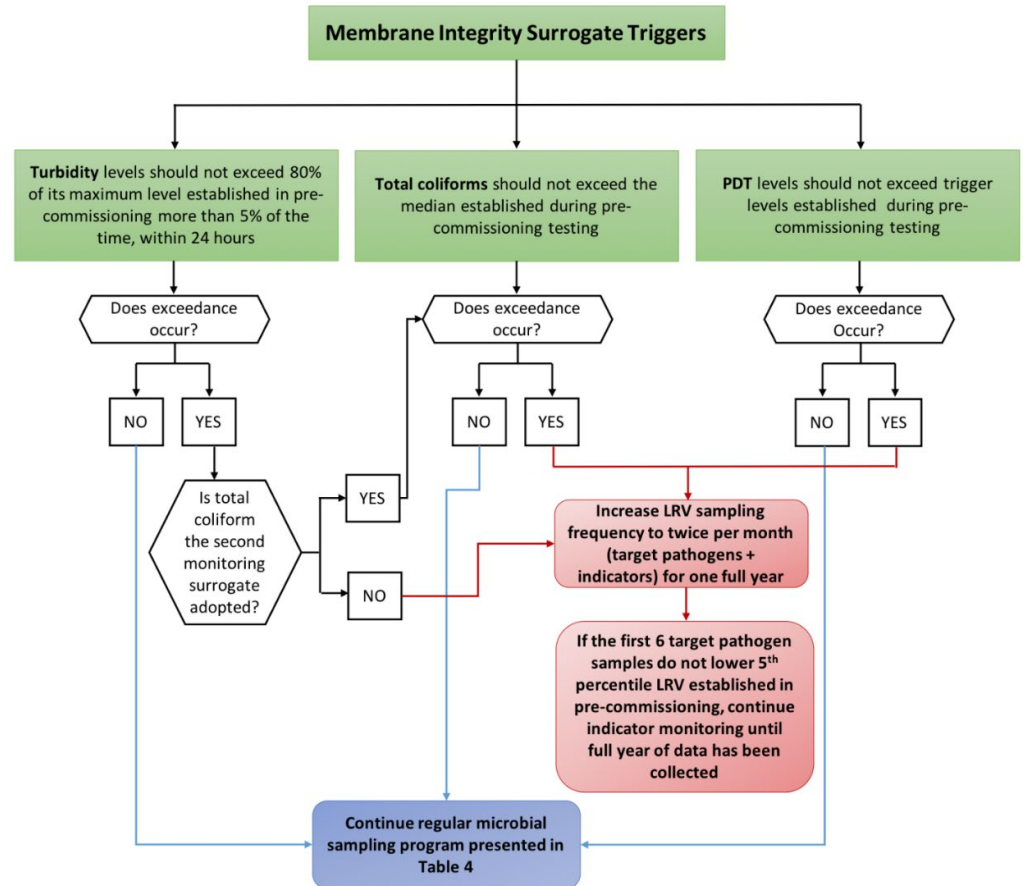


Surrogate #3 – Total Coliform



Tier 2 – Membrane integrity confirmation

- Choose a technique to verify membrane integrity daily
- Exceedances may trigger increased pathogen or surrogate verification frequency



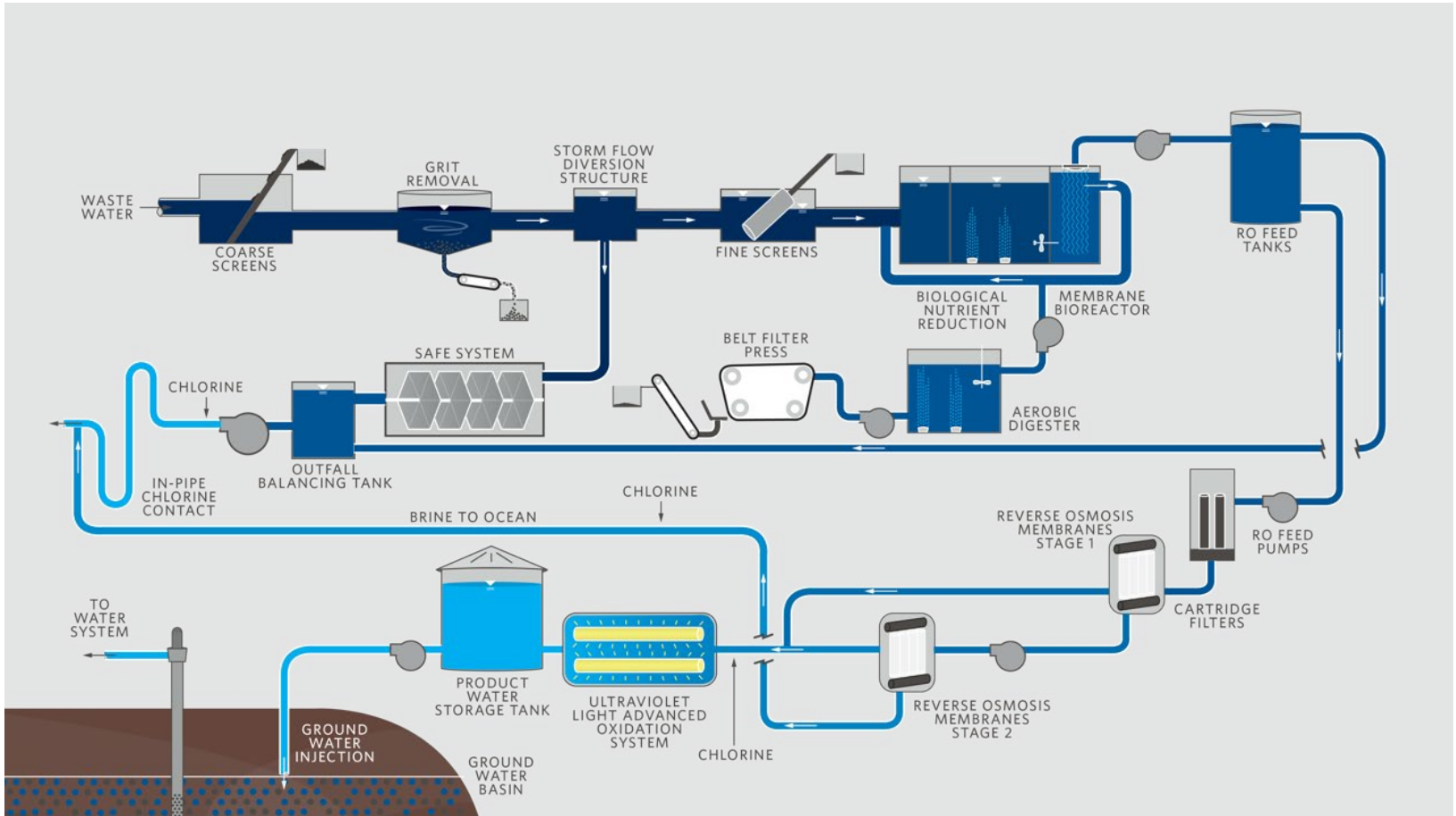
Protocol Is a Living Document

- The protocol should be considered living and updated as new information becomes available
- With supporting information, a testing sponsor may propose alternative surrogates for the regulators' consideration, such as:
 1. Silt density index (15 min)
 2. Large volume total suspended solids
 3. Adenosine triphosphate
- Future considerations:
 1. Evaluate suitability of the target pathogens
 2. Re-evaluate optimal microbial indicators for the target pathogens
 3. Correlation between surrogates and pathogen LRV
 4. Relationship between MBR operating conditions and pathogen LRV
 5. It is recommended that the protocol be reviewed periodically (e.g., every 5 years) to incorporate new information

Tier 2 – Why do it?

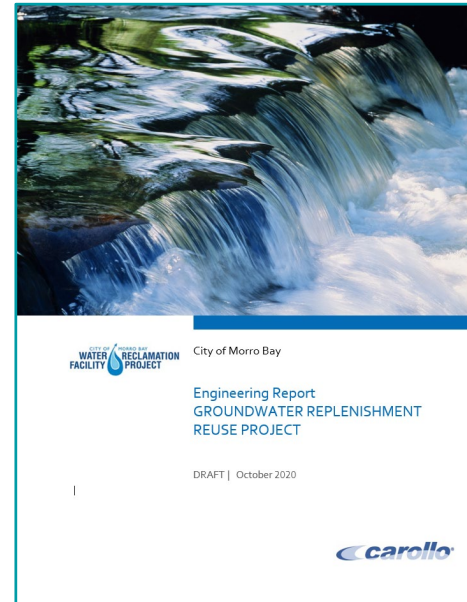
- Tier 2 is more intensive and potentially more expensive due to additional long-term monitoring.
- A greater LRV from Tier 2 may be required in situations where there is not sufficient subsurface travel time to aid treatment.
- Tier 2 may save on installation of additional unit operations.
- Tier 2 would reward well operated systems with a higher LRV than Tier 1.

Case Studies – Morro Bay



Case Studies – Morro Bay

- Tier 1 LRVs suitable
 - Smaller Facility 1 – 2 mgd.
 - Minimizes costly pathogen sampling.
 - Diversion not critical for water supply at this time.
- Additional supplier specific data investigated to demonstrate higher LRVs.
- DDW has yet to decide upon this project



Process	MBR	RO	UVAOP	Aquifer/ Free Cl ₂	Total
Protozoa LRV	2.5	1.5-2.0	6	0	10-10.5

Case Studies – Sterling Natural Resource Center (East Valley WD)

- 8 MGD MBR – UV facility
- Indirect potable reuse project
- Pursuing Tier 1 LRVs
- DDW has yet to decide upon this project



Case Studies – Lake of the Pines – Kubota Tier 2

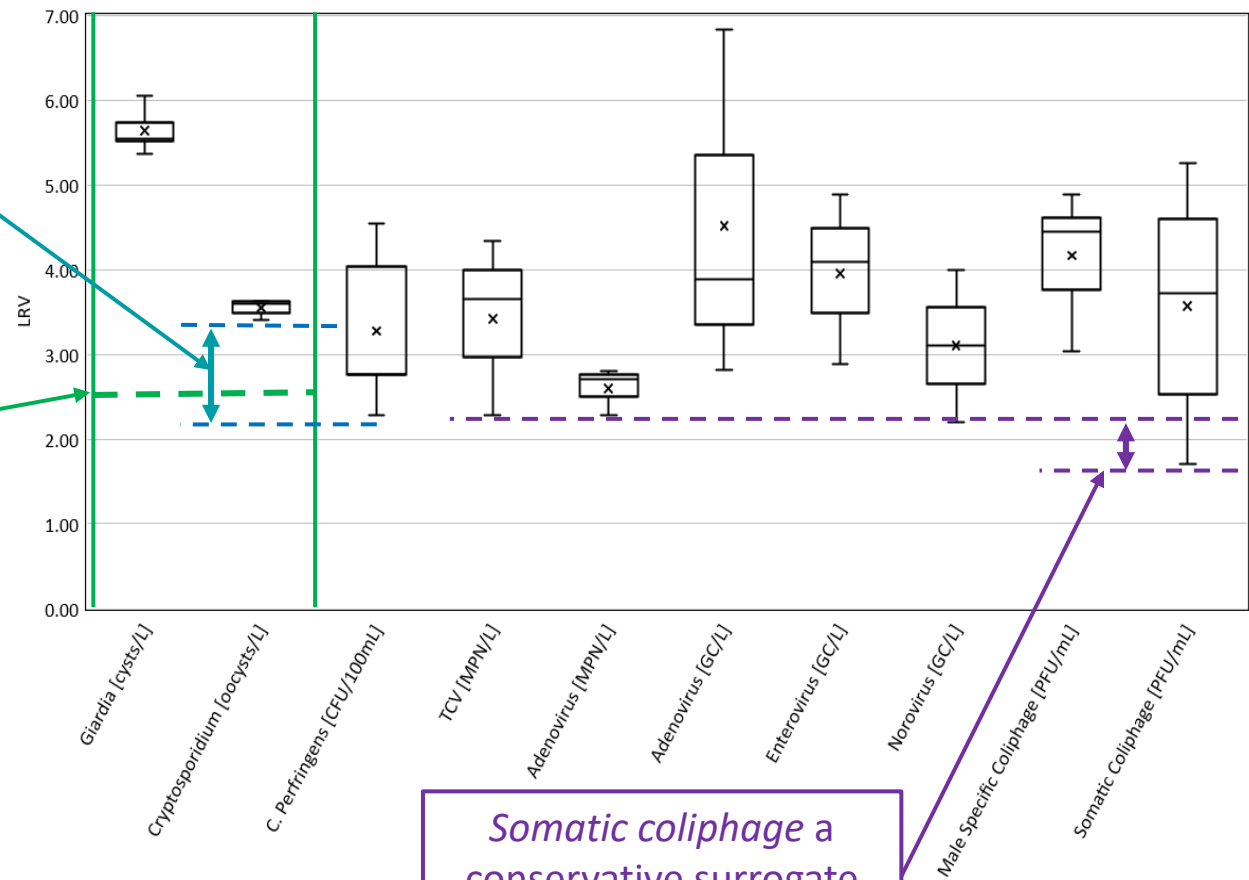
- Very unique plant:
 - 10 year old MF membranes
 - More full scale pathogenic virus and protozoa
- Also investigating Tier 3 surrogates – filtrate TSS monitoring, PMMoV.
- Ongoing work



Case Studies – Lake of the Pines – Kubota Tier 2

C. Perfringens a conservative surrogate for *Cryptosporidium*

MBR target for 10 LRV protozoa removal exceeded



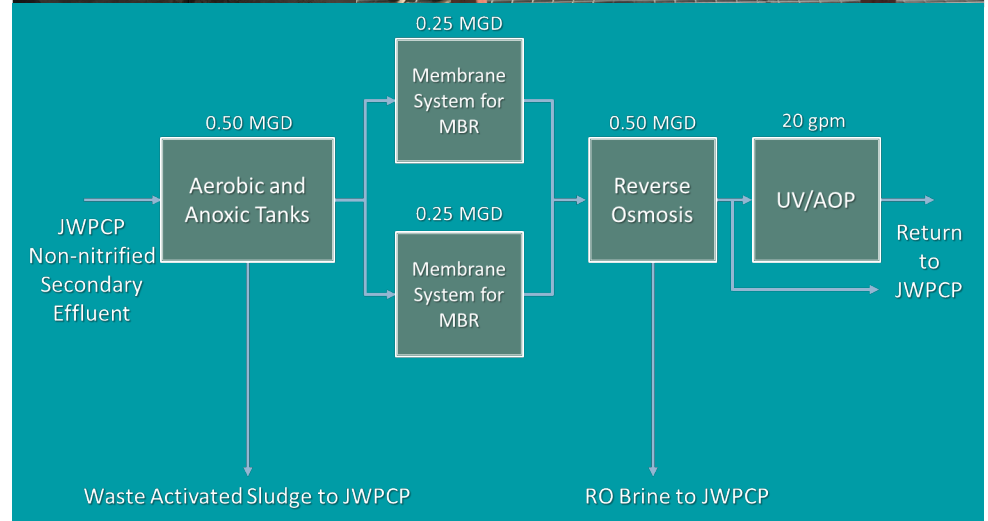
Cryptosporidium removal typically > 3 LRV, not detected in filtrate.
Virus removal typically > 2 LRV, not detected in filtrate

Somatic coliphage a conservative surrogate for viruses



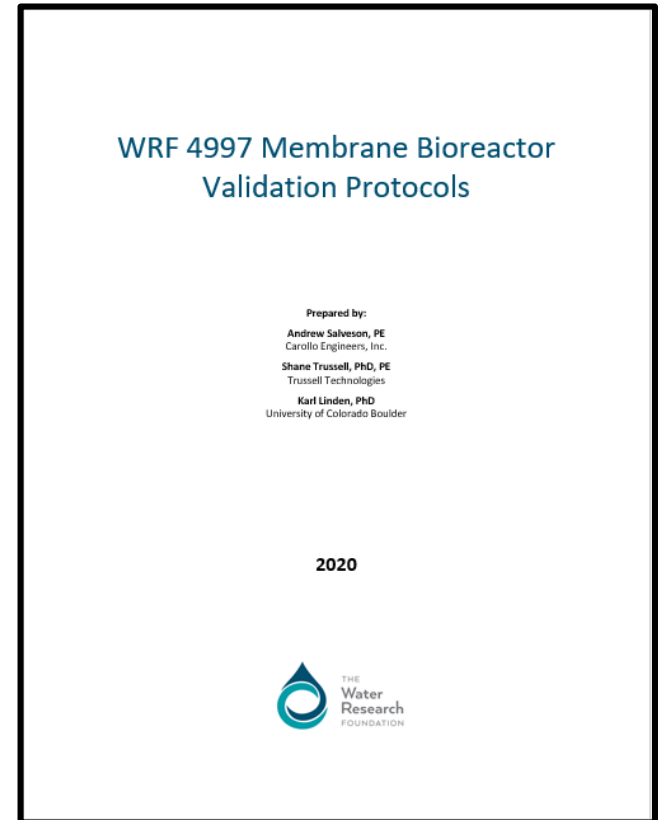
Case Studies – Advanced Purification Center at the Joint Plant

- Metropolitan Water District and Los Angeles County Sanitation District
- Evaluating tertiary and secondary MBR configurations
- High volume microorganism sampling to enhance protozoa detection limit
- Monitoring will be conducted on DuPont and Suez MBR membranes
- Project will have significant impact on potable reuse applications considering MBR



Project Benefits - Close

- Tier 1 LRVs reduce design risk of incorporation of MBR in IPR (12,10,10 possible)
- Detailed protocol and guidance now available for Tier 2 validation:
 - Helps regulators, suppliers and utilities





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Questions?





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Thank You

Comments or questions, please contact:

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For more information, visit

www.waterrf.org

