Response to the Independent Science Advisory Panel Workshop No. 2 Report

Question 1: What are the Panel's suggestions on the MBR testing progress, including microbiological method development and preliminary microbiological and pretesting performance results?

1. The Panel supports the plan for influent on-line surrogate monitoring at the JWPCP to understand contaminant spikes as part of a multi-barrier approach. These on-line parameters can include oxidation reduction potential (ORP), pH, electrical conductivity (EC), temperature, turbidity, ammonium, and others. This information should be linked to monitoring the reverse osmosis (RO) product water quality as well (total organic carbon (TOC), nitrate, EC, etc.).
    a. The goal of using RO product water monitoring with surrogates in support of establishing LRVs for microbial agents appears well embedded in the program.

Response: Acknowledged.

    b. On-line physical/chemical monitoring of RO and final product water will also be used, but should be expanded to identify water quality characteristics that will guide further treatment or polishing of water that enters satellite plants.

Response: Routine monitoring performed throughout the testing period includes quarterly sampling of final product water for CECs, Priority Pollutants, constituents with California NLs and MCLs, and Basin Plan objectives for the Santa Ana and Los Angeles Regional Water Quality Control Boards, which are anticipated to aid in guiding downstream treatment processes and water quality goals. See additional comments on this topic below item 1.c. response.

    c. Monitoring TOC of RO product water could be an important tool for real-time detection of chemical spills that penetrate the RO membrane. "Spills" refers to industrial discharges within the sewershed, which pass through, at some level, primary and secondary treatment at the wastewater treatment plant. There are a number of reasons why detection spikes could occur, beyond spills in the sewershed. Therefore, spills are a subset of spikes and should be separate. Other reasons for spikes can be related to operational issues within the primary or secondary treatment processes.

    The RO will limit these chemicals to low molecular weight, non-polar, and volatile chemicals. The on-line monitoring approach can also be used to help rapidly identify the source(s) of spills. If an anomaly is detected, this can trigger immediate, strategic sampling to capture the spill as it passes through the advanced purification center (APC) plant. Targeted chemical analysis of samples can help identify which permitted discharger is responsible. Once likely dischargers (those using the chemical(s) in bulk) are identified, appropriate monitors for such spills could be distributed within the sewershed to allow for detection and action closer to the source.

    On-line TOC probes, such as those used by Orange County, can be used at this site. These sensors are sensitive in the 10s to 100s ppb range. After setting up the TOC and other sensors, the sensors detect anomalies by a deviation from normal operating baseline conditions. As part of critical control points, sensors must be integrated into the supervisory control and data acquisition (SCADA) system and anomaly detection software. New demonstration testing will provide opportunities to develop and train such software.

Using multi-component monitoring that detects anomalies in the upstream wastewater system is becoming more common. This process can be compared to TOC anomaly detection in permeate.

Response: Acknowledged. It is understood that industry research on the topic of chemical peaks is ongoing and that there is potential to improve real-time monitoring of RO permeate water quality with an appropriate response to anomalies. For the demonstration facility RO permeate, online TOC and UVT are currently measured and monitored in the SCADA system. The Metropolitan Water District of Southern California (Metropolitan) has also procured the same online TOC analyzer that has been used at the Orange County Water District for the Groundwater Replenishment System for installation on RO permeate to provide a lower detection limit as well as a wider measurement range. In addition, the Sanitation Districts of Los Angeles County (Sanitation Districts) have an existing source control program which includes a protocol for source control identification and investigation. In a future potential full-scale advanced water treatment facility, real-time monitoring alerts for any anomalies in RO permeate TOC or UVT levels could be used in conjunction with the Sanitation Districts' source control program. Evaluation of the current demonstration facility RO permeate monitoring and response will provide the opportunity to identify potential improvements for the existing Sanitation Districts' source control program to support future potable reuse of the Joint Water Pollution Control Plant (JWPCP) effluent.

2. The Panel had several observations about nitrogen. It is important to understand the sources and dynamics of nitrogen loading into and through the JWPCP, and how problematic nitrogen species are produced in the MBR. Since ammonia drives design and operation of the MBR, continuously measuring MBR influent ammonia would help understand influent variability. Also, identification, characterization, and the fate of industrial sources of organic nitrogen, which can inhibit nitrification, and other nitrification or denitrification inhibitors would be helpful. (Resources on typical levels of organic nitrogen found in the domestic fraction of wastewater include Pagilla et al. (2008), Urgun-Demirtas et al. (2008), Bronk et al. (2010), and Mesfioui et al. (2012). References on nitrification inhibitors include Hockenbury and Grady (1977), Kelly et al. (2004), and Nowak (1993).)

Response: Acknowledged. Metropolitan is has recently procured the reagent-based Hach Amtax sc Ammonium online analyzer with its pre-filtration Filtrax unit that allows it to be used in potentially high solids process samples at the demonstration facility, including the influent wastewater supplies (currently non-disinfected secondary effluent). This on-line data is anticipated to help develop a clear picture of the diurnal variability observed at the JWPCP.

At Workshop No. 2, the influent organic N concentrations were reported for grab samples collected and analyzed using the Hach Simplified TKN Method. The panel indicated that the relatively high level of organic N observed in the influent could reflect industrial sources of organic nitrogen, which can inhibit nitrification and/or denitrification. The project team investigated this topic by reviewing JWPCP's historical effluent data and the analytical procedure for any potential issues.

Figure 1 below presents the past 10 years of total organic nitrogen (TON) in composite samples of disinfected JWPCP secondary effluent analyzed for compliance. The median TON concentration was 2.55 mg/L-N while the 95th percentile value was 5.15 mg/L-N. It is important to note that these data represent the TON (not dissolved organic nitrogen (DON)) in the JWPCP secondary effluent. Using this information and typical secondary effluent TSS data, the dissolved organic nitrogen (DON) level was estimated at approximately 1.5 mg/L-N. This DON level is similar to levels reported by other plants (USEPA, 2010). As such, at least based on historical data, JWPCP secondary effluent does not appear to contain elevated levels of recalcitrant organic nitrogen, in contrary to what was suggested during Workshop No 2.

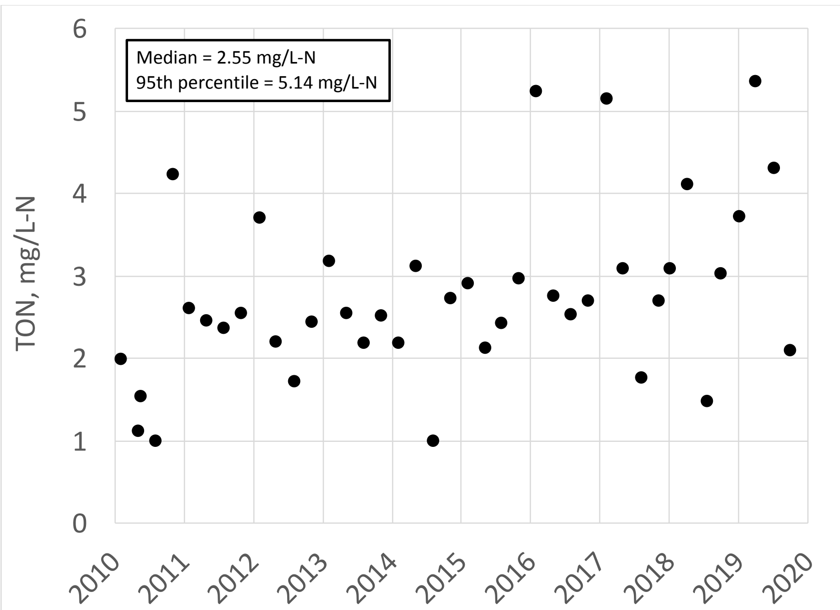

Figure 1. Ten years of Sanitation Districts lab total organic nitrogen data from secondary effluent composite samples

To resolve the discrepancies in TON between the project team's and JWPCP's historical data, additional investigation was conducted. The project team has found that the dilution factor used during sample analysis can affect the results. To maintain consistency, a 5x dilution factor was applied for analyses after 11/20/19. Data prior to 11/20/19 was not always diluted at 5x and may contain more analytical noise (Figure 2).

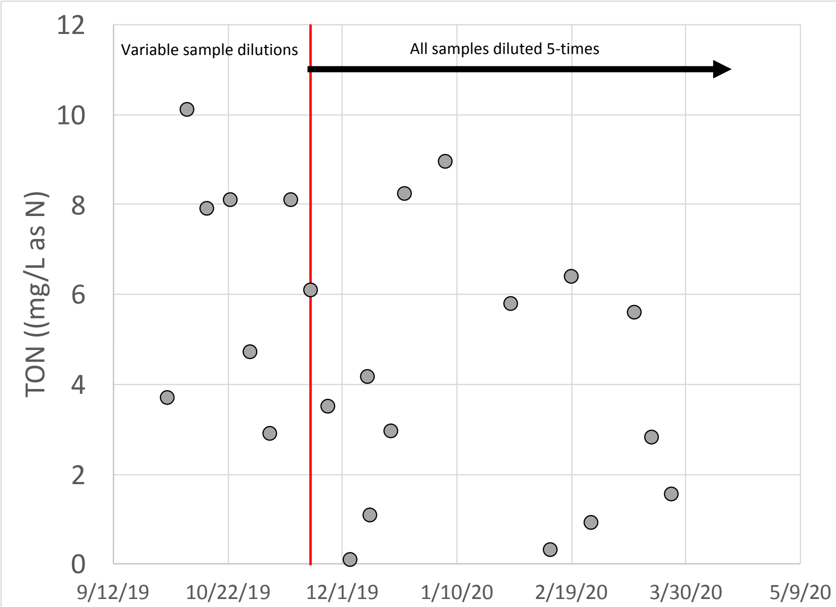

Figure 2. Five months of APC lab total organic nitrogen results from secondary effluent grab samples

In addition, to further support the investigation, a split composite sample of the secondary effluent (APC influent) was analyzed in triplicate by three different labs: Sanitation Districts' lab, Metropolitan's APC lab, and Eurofins Analytical. Table 1 presents the results. It is noted that there was more variability in the Eurofins and APC labs' results. The ammonia concentrations were similar for the APC and Sanitation Districts' labs, while the highest TKN value was quantified by the Sanitation Districts' lab. Since TKN is the sum of organic nitrogen and ammonia, the additional variability in results from the APC and Eurofins lab could explain why TKN levels are less than NH4-N levels shown. Additional split samples will be analyzed for TKN and ammonia by the APC and Sanitation Districts' labs to further investigate the discrepancies observed for TON levels in secondary effluent.

Table 1. Secondary effluent split composite sample results from JWPCP

Secondary Effluent Composite Sample (2/4-5) Split Results

Lab	TKN as mg/L-N				NH4 as mg/L-N			
	n	Mean	Median	St. Dev.	n	Mean	Median	St. Dev.
APC	3.0	48.9	48.7	2.5	3.0	49.0	48.9	1.3
LACSD	3.0	51.3	51.4	0.7	3.0	49.6	49.5	0.7
Eurofins	3.0	47.7	49.0	3.2	3.0	53.3	52.0	2.3

It is also suspected that grab sample data is more variable than composite data, which will influence the comparison of APC (grab) to the JWPCP compliance data (composite). Figure 3 presents secondary effluent TON results from composite samples (A) and grab samples (B). An observation from this figure is that the composite samples are more consistent, while the grab samples have significant variability. As a reminder, the data presented in Workshop No. 2 were all grab sample results.

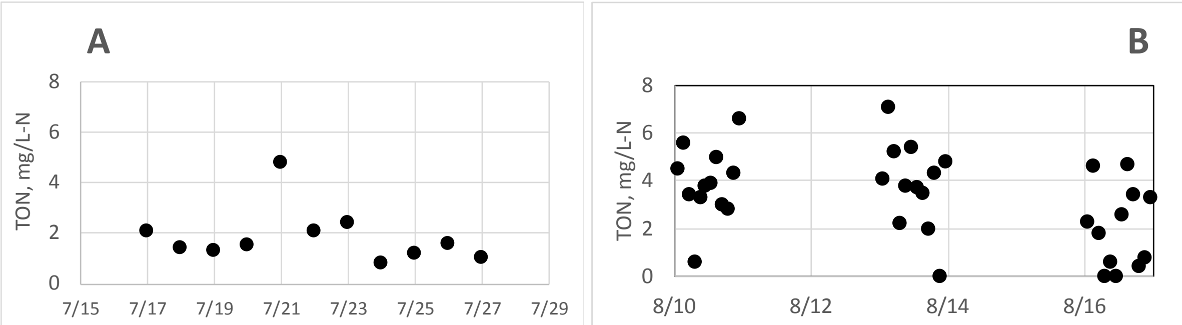

Figure 3. (A) presents JWPCP secondary effluent composite data and (B) presents grab data analyzed in the summer of 2016

The Panel has several other observations:

a. The cause of nitrite building up in the MBR should be clarified, and a plan should be developed to prevent nitrite buildup.

Response: A subgroup of the project team has been meeting on a weekly basis since this issue was identified, with routine participation and input from Dr. David Jenkins. Systematic steps have been taken to address this issue, including the following:

- Batch reactor testing to assess nutrient deficiency, alternative carbon sources, multiple carbon addition points, non-competitive inhibition (e.g., free nitrous acid), and specific denitrification rates on a routine basis
- Microbial assessment for the abundance/presence of glycogen accumulating organisms and polyphosphate accumulating organisms (GAOs/PAOs) known to store glycogen/polyphosphates and ultimately inhibit denitrification
- Implementation of high hydraulic retention time (HRT) and high carbon dose to meet COD demand in the anoxic basin
- Implementation of low solids retention time (SRT) of 8 days to wash out undesirable GAOs (Onnis-Hayden et. al., 2019).

Results of optimization efforts to minimize nitrite build up will be implemented prior to baseline testing at the demonstration facility.

b. The Panel is interested in seeing the post-RO nitrogen information.

Response: Based on weekly operational monitoring data from October to December 2019, post-RO nitrogen species (and MBR filtrate for reference) have been as summarized in Table 2 below. Data shown includes performance under un-optimized, non-steady-state conditions and intermittent operation.

Table 2. Weekly operational monitoring data from the demonstration facility

	Secondary Effluent, Screened Min-Max; Median	**MBR Combined Filtrate Min-Max; Median**		**RO Permeate Min-Max; Median**
Operational Conditions				
		MBR1	MBR2	
Flux (gfd)		11.7-13.7; 12.1 (n=60)	11.0-13.4; 12.3 (n=60)	
TMP (psi)		0.4-0.6; 0.5 (n=58)	1.5-2.5; 2.0 (n=58)	
Recovery (%)				80-86; 85 (n=51)
Aerobic HRT (hrs)	2.0-3.6; 2.6 (n=58)			
Anoxic HRT (hrs)	1.8-3.2; 2.2 (n=58)			
SRT (days)	6.8-56.3; 14.7 (n=57)			
MLSS (mg/L)	4,973-11,800; 7,316 (n=64)			
Water Quality Conditions/Performance				
pH	Aerobic = 6.6-7.9; 7.3 (n=65) Anoxic = 6.8-7.8; 7.2 (n=58)	6.3-6.8; 6.6 (n=53, MBR filtrate)		4.9-5.7; 5.2 (n=50)
Chlorine, total (mg/L)				ND-4.8; 1.4 (n=63, RO feed w/chem. added)
Ammonia (mgN/L)	38.0-45.7; 41.9 (n = 18)	ND (n = 11)		ND – 0.6; 0.2 (n = 13)
Nitrate (mgN/L)	0.2 – 0.3; 0.2 (n = 18)	5.6 – 38.4; 18.4 (n = 11)		0.5 – 2.9; 1.4 (n = 13)
Nitrite (mgN/L)	ND – 0.1; ND (n = 18)	0.2 – 28.9; 5.0 (n = 11)		ND – 2.3; 0.3 (n = 13)

c. The Project can consider other sources of organic carbon to support denitrification, such as exogenous or internally generated acetic acid. Alcohols are often used, but acetate gives good kinetic performance; please consider the WRF report: https://www.waterrf.org/research/projects/protocol-evaluate-alternative-external-carbon-sources-denitrification-full-scale as well as this paper: https://iwaponline.com/wst/article-abstract/60/10/2485/17721

Response: The project team has evaluated improvement in denitrification with potential alternative carbon sources such as MicroC 1000, blends of MicroC 1000/2000, and acetate. In addition, EOSi provided support to try to identify an appropriate blend of MicroC 1000/2000 for optimal denitrification under nitrification-denitrification (NDN) mixed liquor conditions. While the use of methanol at the demonstration facility is not considered at this time due to safety concerns, a side-study will be conducted using demonstration facility biomass that has been acclimated to use methanol in order to asses denitrification efficacy with a non-glycerol based carbon source.

d. To speed up adaptation in the AWT bioreactors and keep the project on schedule, it is worth considering alternate seeding sources, for example, from a facility that nitrifies and denitrifies.

Response: Acknowledged; alternate seeding sources may be evaluated on a smaller pilot-scale using a sequencing batch reactor. However, it is anticipated that any seeded biomass would not be retained if GAOs are being grown in the system due to the environment created by the demonstration facility design and carbon type used. With glycerol making up 70-74% of MicroC 2000 (with the remaining percentage being mostly water), it is anticipated that GAOs would eventually proliferate over non-GAO denitrifiers present in nitrifying-denitrifying sludge.

e. The mainstream anammox process has matured and may be a promising option.

Response: Anammox studies have been performed at the JWPCP, including pilot-scale evaluations of Kruger's ANITA Mox systems for sidestream (Liu et al., 2014) and mainstream applications (Liu et al., 2018; Krikorian et al., 2019). Results of the latter showed that over a 9-month period, median effluent TN of 15 mgN/L with residual ammonia of about 5 mgN/L and nitrite below 1 mgN/L could be achieved. Depending on the discharge/downstream process requirements, the latter two species can be polished using a high-rate (e.g., MBBR or BAF) nitrifying process. While the pilot test results were encouraging, it was considered too premature for the Program as no full-scale, mainstream anammox facilities are in operation at the scale of the Program's potential full-scale AWT facility.

It should be noted that this technology was discussed during the Advisory Panel workshop for the Feasibility Study in 2016 and deemed not ready for inclusion in the demonstration facility due to the lack of evidence on scalability to a large 150-mgd potential facility. During the workshop, it was noted that there could be applicability for sidestream nitrogen removal from JWPCP centrate, which could reduce the overall nitrogen load to an AWT facility. These recommendations are summarized in the workshop report[1]. The anammox process was also assessed during the Nitrogen Management Study in 2018 as a potential alternative for nitrogen removal[2]. It was again deemed as not sufficient of a mature technology for use as a mainstream secondary or tertiary process, but potentially for sidestream centrate treatment, due to its lack of installation in full-scale studies. The resulting five treatment process trains recommended for further evaluation, however, did not include deammonification through the anammox process. The project team plans to re-assess the applicability of this process at a later time.

f. Note that MBRs create smaller flocs than gravity clarifiers in suspended growth systems, making them more vulnerable to soluble inhibitors (Henriques, et al., 2005). The demonstration team should be aware of this.

Response: Acknowledged.

3. Methods development.

a. The Panel was impressed with the work staff has done on methods development and supports the development of a proposed pathogen/indicator suite to allow LRV determination.

[1] http://mwdh2o.com/PDF_About_Your_Water/Advisory%20Panel%20Report%20on%20Demonstration%20Plant%20Design%2006302016%20FINAL.pdf

[2] http://www.mwdh2o.com/DocSvcsPubs/rrwp/assets/2-rrwp_conceptual_planning_studies_report_appendices_only_02212019.pdf

Response: The panel's comment is greatly appreciated.

b. The Project should develop criteria for rejecting analytical data, especially related to recovery data. The Panel would be interested in seeing the QA/QC program.

Response: The project-specific quality assurance for microbiological samples is included in the approved testing and monitoring plan Appendices E and H for Metropolitan and the Sanitation Districts, respectively[3]. As stated in Appendix E, standardized methods for *Cryptosporidium* and *Giardia* applicable to the sample types and volumes included in the current testing plan are lacking. The same is also generally true for the indicator organisms being monitored. Therefore, by the end of the baseline testing period enough data should be generated to allow establishment of acceptable matrix spike recoveries. The statistical approach described in EPA Method 1693 will be followed for determining matrix spike recovery acceptance criteria for *Cryptosporidium* and *Giardia.* EPA Method 1693 acceptable recoveries for 10 L matrix spike samples are 29 – 100% for *Cryptosporidium* and 21 – 100% for *Giardia*, but the method states that not all matrices will allow this to be achieved. The ongoing Water Research Foundation Project 4952 (California State Water Resources Control Board DPR-2) has proposed acceptable recoveries for 1 L raw wastewater matrix spike samples of 29 – 100% for *Cryptosporidium* and 10 – 100% for *Giardia*. Acceptable recoveries for the demo plant testing plan will likely be similar for *Cryptosporidium* and *Giardia* and approximately 10 – 100%.

c. The Project should consider that seasonal variation in water quality (for example, due to wet weather and temperature variation) could affect valid LRV challenge testing. Appendix D contains reference information related to pathogen survival.

Response: Pathogen concentrations will be measured over a 15-month testing period and so a certain level of seasonal variability will be captured by the probabilistic approach to determining LRV. In addition, future testing beyond this first 15 months will provide additional data that will capture seasonal variability.

4. Pretesting results.

a. The Panel commends the project team's coordination/cooperation on microbiological analyses. It will be important to understand the variability of source contributions in the sewershed, for example, wastewater from hospitals. The Panel would like to understand what the current thinking is about operational responsibility for stable water quality from JWPCP to the AWT.

Response: Acknowledged. Understanding the variability of source contributions is important. This analysis will be considered as part of an update to the Sanitation Districts' existing enhanced source control program. In addition, the Sanitation Districts will work with Metropolitan staff to determine the best possible way to divide operational responsibility to ensure stable water quality to the AWT. Water quality acceptance criteria has not yet been defined for the effluent stream from JWPCP which will be used as the demonstration facility influent. This will be explored further in a future phase of testing following results obtained during the current testing phase.

[3] http://www.mwdh2o.com/DocSvcsPubs/rrwp/assets/mwd-lacsd_demo_test_plan_2019_with_submittal_letter.pdf

b. Secondary and tertiary MBR effluents are not the same. For example, fragrances and other volatile organic compounds (VOCs) are more likely to be present in primary effluent than in secondary effluent, which is exposed to extended air sparging during aeration. While not a public health concern, fragrances and other nonregulated VOCs can cause aesthetic issues (such as odor) that consumers can detect. Many VOCs are neutral organic molecules and can pass through RO membranes. Public perception is an important aspect of this project. On-line monitoring, as discussed in item 1, can help identify when problematic levels of these chemicals are present in the MBR effluent/RO influent.

Response: Acknowledged. The Sanitation Districts agree that secondary and tertiary MBR effluent may not be the same and that there is a need to understand and characterize primary effluent vs. secondary effluent to assess presence or absence of volatile compounds that are currently removed during the secondary treatment process at JWPCP. Monitoring for a variety of CECs will be conducted and other suggested analytes could be added to the monitoring list. It is anticipated that the online TOC analyzers at the demonstration or potential full-scale facility will provide the sensitivity needed to capture any anomalies in RO feed and permeate, such that potential concerns for aesthetic issues caused by odor causing compounds and VOCs that pass through the RO membrane can be addressed.

c. The Panel is interested in how Tier 3 of the Australian Three-Tier Concept for MBR removal of pathogens correlations will be developed.

Response: While it is not anticipated that a Tier 3 result will be obtained, a Tier 3 approach would require the development of a correlation between pathogen LRV and a parameter that can be monitored continuously at the feed and filtrate of the MBR system. A possible Tier 3 approach is to use turbidity, total suspended solids, or pressure decay test results as a surrogate measure for suspended solids. As this approach is based on artificially varying the system removal performance while simultaneously measuring an online water quality parameter and carrying out challenge testing, turbidity and pressure decay tests will be continuously monitored during baseline and compromised system testing. Transfer of suspended solids into permeate would most likely be detectable by turbidity monitoring if a fiber breach were to occur. This Tier 3 approach relies on the assumption that the LRV of suspended solids is equal to the LRV of pathogens across the membrane, implying that turbidity can be correlated to pathogen LRVs provided the relationship between turbidity and suspended solids removal is well established.

Question 2: What analyses do the Panel suggest in order to validate overall log reduction values for the treatment process, with a focus on MBR treatment of primary effluent?

1. The Panel believes the current 2020 testing plan (four month/eight month split) appears reasonable. The plan for 2021 and secondary MBR appears to appropriately mimic the tertiary MBR sampling plan. All the documents assume denitrification is required. Denitrification is beneficial and adds important, multiple barriers that provide chemical and microbial control benefits. Denitrification also adds a very high cost to the capital and O&M of this project. However, RO can remove more than 75 percent of the nitrate and nitrite. The document should include a brief justification for why biological denitrification is a critical element in the design.

Response: Comment noted. Nitrogen removal through biological denitrification has a high O&M cost compared with nitrogen removal through RO rejection, however, based on initial cost evaluation, may have had lower life-cycle cost than that of physical rejection through RO. This no longer seems to be the case based on actual performance observed at the demonstration facility. The current treatment train being evaluated employs the former for denitrification, however, four other options will be considered for overall nitrogen management to meet product water quality goals. One of the other five options considers nitrogen removal though membrane filtration with double pass RO. Metropolitan and the Sanitation Districts will continue to meet with the Panel to evaluate nitrogen management at a program level and discuss any recommended changes to the approach.

To provide some additional background, in 2018, a Nitrogen Management workgroup consisting of representatives from the Sanitation Districts and Metropolitan evaluated various treatment process alternatives that could be considered at JWPCP and/or a future potential full-scale AWT facility for reducing nitrogen in the final AWT product water through a more holistic management strategy. Based on a review of previous work conducted by the Sanitation Districts (Sanitation Districts of Los Angeles County, October 2016), 18 unit processes were assessed that could replace or retrofit the existing secondary, be added on as a tertiary process, or treat centrifuge centrate streams. These processes were used to form 17 different process trains. Based on cost and ability to meet target water quality goals, five process trains remained as possible alternatives for further consideration:

1. NdN Secondary MBR (Retrofit) + Single-Pass RO
2. NdN Secondary MBR + Single-Pass RO
3. NdN Tertiary MBR + Single-Pass RO
4. N-only Tertiary MBR + Two-Pass RO
5. MF + Two-Pass RO

The Conceptual Planning Studies report used Option 3, NdN Tertiary MBR + (single pass) RO, as the "base-case" treatment train for the evaluation, and the configuration is the treatment train that is intended to be used during the current phase of demonstration testing. Option 4, a Nitrification-only (N-only) Tertiary MBR + Two Pass RO, has been identified as a potential alternative treatment train for nitrogen management and is anticipated to be evaluated at demonstration scale. The summary report is entitled "Nitrogen Management Evaluation for Full-scale Advanced Water Treatment Facility", which can be found in Appendix C of the Conceptual Planning Studies Report[4].

A more detailed life-cycle cost estimate would need to be conducted with operational design criteria assumptions to assess whether more frequent RO membrane replacement (in a double-pass configuration) to minimize end-of-life degradation in NOx rejection and maintain consistent nitrogen rejection would be less costly than biological denitrification and associated chemical usage costs. In addition, other impacts, such as the overall reduction in nitrogen load in JWPCP waste streams with biological denitrification versus physical removal through the RO, would need to be assessed.

2. Analytical methods for *Giardia* and *Cryptosporidium* should mimic the State Water Board/WRF Grant–Direct Potable Reuse (DPR) Project 2 raw wastewater methods.

Response: Metropolitan's *Cryptosporidium* and *Giardia* method is a modification of EPA Method 1693

[4] http://www.mwdh2o.com/DocSvcsPubs/rrwp/assets/2-rrwp_conceptual_planning_studies_report_appendices_only_02212019.pdf

and is similar to the method being used for DPR-2. It should be noted that 1 L raw wastewater samples are being analyzed for the DPR-2 project, while 10 L non-disinfected secondary effluent and 10,000 L MBR filtrate samples are being analyzed for the current demo plant testing plan. Therefore, the methods are similar but not identical.

3. The Project should conduct LRV challenge testing on membranes from both vendors, under the same conditions, during the second phase of MBR testing. The question of whether LRV testing would need to be expanded to other potential full-scale, AWT-qualified MBR vendors that were not installed or tested at the demonstration facility should be posed to the regulator.

Response: The current approach does not consider equivalent sampling from both vendors; however, this will be considered during further development of the secondary MBR test plan. Previous resource limitations within Metropolitan to process samples for pathogens reduced the MBR filtrate sampling scope primarily to one vendor; however, these limitations could be addressed in the future by sending the samples out for analyses to an outside laboratory, for example. The project team is working closely with the regulators on development and implementation of the testing plans, as well as development of design criteria for a potential future full-scale facility.

4. Membranes are backwashed and cleaned to address possible biofouling (implying biofilm features). The Panel believes the Project should consider variation in degree of biofouling with distance from the vacuum header when identifying fibers to cut. A standard operating procedure should be developed for fiber severing.

Response: The variation in degree of biofouling with distance from the vacuum header when identifying fibers to cut will be taken into consideration; however, it is anticipated that cutting fibers close to the filtrate header will best simulate severe fiber damage and maximize the amount of suction through the cut fiber, thereby increasing the likelihood of mixed liquor passing through the system. This is the methodology used as part of Santa Clara Valley Water Districts' Membrane Bioreactor Demonstration for Potable Reuse (Santa Clara Valley Water District, 2017). A standard operating procedure for fiber severing is currently being developed and is included in Attachment 1 of this document.

5. LRV should be based on recovery-adjusted concentration. Consider using more frequent controls to estimate recovery. Recovery standards can run in parallel on every analytical run, so recovery efficiency would be measured for every run and every day. Some projects report recoveries and don't correct answers if recoveries are 90 percent or better. Recovery adjustment would provide a more accurate estimate of actual numbers in the environmental samples. Otherwise, there is the potential to underestimate risk from pathogens by creating false negatives. With time, recovery variability will help provide bounds of confidence around the repeatability of recovery.

Response: As stated in the test plan and during the workshop, a ColorSeed spike is being added to every sample that is analyzed for *Cryptosporidium* and *Giardia*. Therefore, recovery efficiency will be determined for all samples and pathogen concentrations will be adjusted for recovery.

6. The Project can consider the value of DNA sequencing to understand pathogens. This analysis may complement some of the pathogen culture work and help identify the most dominant microorganisms and genes that are present before and after key unit processes. This approach

may also identify selected microbial taxa that provide beneficial information and can be analyzed more frequently by specific and more quantitative methods. Consideration can be given to sequencing only intracellular DNA, and to confirming the viability of potential microbial pathogens identified by DNA-based methods using culture-based methods. Relevant references include Stamps et al. (2018) and Papp et al. (2020).

Response: Molecular and viability analyses are not necessary for demonstrating pathogen LRVs for full-scale design and permitting purposes. However, we recognize the value in gaining a more thorough understanding of the microbiology of the treatment processes. Consequently, samples from the aerobic and anoxic tanks have been collected and stored frozen, and we will continue to periodically collect samples from various locations within the plant throughout the testing period. These samples can be used for molecular characterization, phylogenetic analyses, and species identification at a later stage of demo plant testing, depending on time and resource availability.

7. The Panel supports following the Hazard Analysis and Critical Control Points (HACCP) framework. Reliability assurance is a critical issue. Simply adding LRVs is not an optimal way to address deviations. Failure Mode and Effects Analysis (FMEA), is another approach to reliability that involves looking at each component of a treatment train—such as how each process depends on the performance of other processes in the full system, including influent quality, the effect of the effluent quality of each process on downstream process performance, pumps, piping, analytical procedures, and monitoring requirements. It then considers what the effects of a deviation would be and how the adverse effects can be avoided and what to do in the event of a deviation. The detailed analysis is carried out by a group of experts knowledgeable in all aspects of a given system. The FMEA process facilitates decisions on the need for duplicate processes, influent and effluent monitoring requirements, the need to keep critical spare parts on hand, the need for critical items to be researched, etc.

   These analyses are a final design issue since they mainly pertain to the O&M manual and monitoring for maintaining operational control, recognizing that Metropolitan is essentially applying HACCP/FMEA in the preliminary design when pilot MBR/RO/AOP results are evaluated for the purpose of deciding whether or not to use granular activated carbon (GAC) after AOP.

Response: Acknowledged.

8. The high-purity-oxygen activated sludge basin wastewater supply is inadequate to provide the desired flow for both the JWPCP and the AWT under some conditions. The Panel is interested in seeing proposed solutions to address this; for example, equalization, improved distribution of flow across multiple basins, etc.

Response: The Sanitation Districts are currently evaluating the impact of both secondary and tertiary MBR treatment processes on JWPCP as well as the need to provide constant flows potentially through flow equalization for an AWT process that includes tertiary MBR. The Sanitation Districts will be retaining the services of consultants to research various aspects of this project, including potential design options and the best solution to move forward, maximizing operational flexibility and reuse possibilities. A draft report should be available in 2021. Information will be used to identify necessary work for secondary MBR testing.

9. The project team could more clearly articulate and justify the need for biological

nitrification/denitrification. The Panel recommends that the project team state more clearly why ammonium ion rejection by reverse osmosis would not meet the nitrogen goal. Similarly, the use/need for second-pass RO should be discussed.

Response: See response to Question 2, Item 1 for background on proposed alternate treatment trains for evaluation. In addition, a conservative single-pass RO rejection was assumed of 80% for nitrate, 85% for ammonia and 95% for organic nitrogen. With these estimates, it was deemed that denitrification would be needed in conjunction with single-pass RO whether in a secondary or tertiary MBR configuration in order to meet the product water goal of TN ≤ 3.5 mg/L (e.g. NO_3 < 3.4 mg/L-N). With a nitrification-only + two-pass RO or MF + two-pass RO train, denitrification would not be needed.

10. Secondary MBR options will impact sludge handling and should be understood (dewatering, sludge volumes, energy impacts, land application, etc.)

Response: See response to the previous item Question 2, item 8.

Question 3: What preliminary guidance does the panel have regarding provision and achievement of LRV credits for downstream drinking and/or satellite WTPs?

The Panel's initial reaction/guidance regarding raw water augmentation is based on limited information that was presented, including the current assumptions about a 10 percent blend of AWPF water with other source waters; however, the Panel does not anticipate that the logic applied here would be significantly different with a higher blend. The Panel assumes that the water leaving the AWT meets surface water augmentation (SWA) requirements. The Panel assumes the 40-mile pipeline provides an engineered buffer (for example, contact time and reaction time) and establishes a minimum hydraulic retention time in the pipeline that is necessary to provide reaction time to address significant treatment excursions. (Appendix D contains reference information regarding *Cryptosporidium* mortality as a function of time and temperature). Specific post-treatment goals will vary depending on whether the water is spread/injected or introduced ahead of a WTP. The Panel assumes the Project includes enhanced source control, additional treatment to address chemical peaks, and enhanced operations and monitoring. Given these assumptions:

1. Metropolitan should evaluate additional monitoring of the product water leaving the AWT and at the Junction Structure that would affect performance at the Weymouth WTP (for example, turbidity, TOC, conductivity, alkalinity, etc.) and establish critical control triggers. The monitoring should occur at the point where mixing has been complete, at the exit from the Junction Structure at the Weymouth WTP. Water that significantly exceeds those critical control triggers could be rerouted to spreading basins or injection facilities as an additional contingency (assuming the water meets IPR requirements for groundwater spreading/injection). If IPR requirements are not met, the water could be routed to flood control and wasted.

Response: Acknowledged. Metropolitan's existing conveyance system flexibility allows for various options to route AWT product water. Monitoring would be incorporated at a Junction Structure on the AWT conveyance system, and critical control points (CCPs) could be used at this location. CCPs and diversion at the Weymouth Plant Junction Structure could be difficult to incorporate, as flow continues onward from this location to the Diemer Plant, and detention time is on the order of minutes from the

Weymouth Junction Structure to the Weymouth ozone contactor. Alternatively, an intermediate location between the Junction Structure on the AWT conveyance system and the Weymouth Junction Structure could be considered for rerouting of any water that exceeds CCP triggers. Another option if necessary could be for AWT product from the Weymouth Junction Structure to continue onwards through the Yorba Linda Feeder and bypass the Diemer plant to be delivered for recharge at OC-28.

2. The effluent from the Junction Structure should be the sampling point for determining whether the blended water quality falls within the historical range for feedwaters that have been successfully treated under the Surface Water Treatment Rule (SWTR). The Panel believes that as long as the water quality of the blended sources (CRW/SPW/AWT product water measured at the Junction Structure) is within historical source water quality ranges (for example, turbidity, DOC, pH, alkalinity, temperature, EC, and LT2 requirements all statistically characterized) that has been successfully treated, the WTP should continue to receive LRV credits using typical SWTR requirements, such as finished water turbidity and CT.

Response: Acknowledged. The AWT product water blend in Weymouth influent could be restricted to ensure that the resulting water was viable to effective treatment with ozone and conventional treatment. Water quality acceptance criteria for AWT product water would be defined to ensure that blended water quality upstream of a drinking plant was within historical source water quality ranges.

3. The Panel has the following thoughts on a satellite process configuration:

   a. The Panel would like to have access to the technical memo on satellite treatment.

Response: Acknowledged. This memorandum is currently in draft form and will be provided upon finalization, following consideration of the revised language in the State Water Board DPR Framework, 2nd Edition.

   b. Given the current design, and the limited information the Panel has, satellite treatment does not appear to be necessary for LRV credit for IPR projects, but additional treatment may be needed as noted below in item four.

Response: Acknowledged.

   c. Dechlorination will be needed before blending to manage disinfection byproduct (DBP) formation. Dechlorination is recommend at the point immediately before the AWT water blends with any untreated surface water that contains TOC. Otherwise, there is a risk of producing DBPs.

Response: Comment noted. Chlorination/dechlorination will be evaluated further at a later phase of the program. One scenario could consider dechlorination occurring much farther upstream of any blending points, for example.

   d. Potential introduction of the Los Angeles Department of Water and Power AWT water into the regional transmission system may have satellite treatment implications but there is insufficient information to confirm this at this time.

Response: Acknowledged. As the program develops it is our intent to keep the ISAP informed so that input can be obtained on implications of potential introduction of LADWP water into Metropolitan's conveyance system. Metropolitan would specify the LADWP water quality required prior to input into Metropolitan's AWT conveyance system, depending on whether the need is for IPR versus DPR.

e. Satellite treatment for boron management may be required to meet the water quality objective of 0.5 milligram per liter for the Main San Gabriel Groundwater Basin. The current California requirement (0.5 mg/L) is quite stringent; both USEPA (6 mg/L) and World Health Organization (2.4 mg/L) are higher. There might be an opportunity to discuss the issue with DDW to obviate the need and expense for supplemental treatment for boron.

Response: Acknowledged. Metropolitan and the Sanitation Districts will continue to work with DDW and the Los Angeles Regional Water Quality Control Board on this topic.

f. Post-RO GAC could be considered if source water risk assessment demonstrates the presence of certain chemicals in the feedwater.

Response: Acknowledged.

4. Additional processes (ozone, biological activated carbon (BAC), microfiltration (MF)) added to the AWT should only be considered if currently planned processes are deemed insufficient to manage microbial or chemical risks. Full advanced treatment (FAT), is defined in CA Title 22, §60320.201, Advanced Treatment Criteria, (contained in the Groundwater Replenishment Regulations and 60320.302 of the Surface Water Augmentation regulations). FAT, although not mandatory for all potable reuse projects in California (for example, groundwater replenishment via surface spreading), is commonly employed and will, for the near term, be the main treatment train for DPR projects in California. FAT consists of high-pressure membrane filtration (such as reverse osmosis/RO) followed by advanced oxidation processes (AOP). In addition, RO is generally preceded by low-pressure membrane filtration, such as microfiltration or ultrafiltration.

Although FAT does an excellent job of removing organic contaminants of concern, typically low levels (< 0.5 mg/L) of total organic carbon persist in FAT product waters. It has been observed that larger compounds (MW > 200) and/or charged compounds are typically very well removed (>90 percent) by RO membranes (Drewes et al., 2006; Howe et al., 2019), and UV/AOP is an effective process to oxidize key contaminants, such as NDMA and 1,4-dioxane, and likely others that are not fully rejected by RO (Plumlee et al., 2008, Mestankova et al., 2016).

Short-duration chemical peaks have been observed in RO feed and RO permeate at the OCWD full-scale groundwater recharge facility (Olivieri et al., 2016) due to certain low-molecular-weight compounds that are not fully removed by FAT. These compounds were detected by an on-line TOC analyzer that continuously monitors the RO permeate quality.

Response: Acknowledged. It is our intent to closely monitor the RO permeate TOC levels for any low molecular weight and/or charge compounds that pass through RO membranes.

When applied to some wastewater, some processes (such as ozonation) can produce disinfection byproducts (for example, NDMA, aldehydes) that must be managed, because they could pass through MF/RO. Some DBPs are biodegradable and an additional unit process following ozone may be considered if warranted by concentrations, regulations, and calculated risks. Ozone was successfully implemented at the Scottsdale Water campus, which is primarily domestic wastewater, and reduces both NDMA levels post-RO and reduces MF and RO fouling by wastewater organics.

Response: Acknowledged. Any additional processes that may be incorporated into a future potential treatment train, whether for IPR/DPR, will be thoroughly reviewed for their risks and benefits, among others.

References

Liu, M.; Smal, N.; Barry, J.; Morton, R.; Tang, C. C.; Friess, P. L.; Bell, J.; Zhao, H. In *Pilot-Scale Evaluation of ANITA™ Mox for Centrate Nitrogen Removal at the Joint Water Pollution Control Plant*, Proceedings of the WEFTEC '14, 87th Annual Water Environment Federation (WEF) Technical Exhibition and Conference, New Orleans, LA, Sept 27-Oct 1, 2014; Water Environment Federation: Alexandria, VA.

Liu, M.; Krikorian, E.; Knapp, T.; Melitas, N.; Zhao, H.; Johnson, M. In *Mainstream ANITA Mox Pilot Testing at the Joint Water Pollution Control Plant*, Nutrient Removal and Recovery Conference Proceedings, Raleigh, NC, June 18-21, 2018; Water Environment Federation: Alexandria, VA.

Krikorian, E.; Long, H.; Knapp, T.; Liu, M.; Melitas, N.; Zhao, H.; Johnson, M. In *Concurrent Mainstream Deammonification and Phosphorus Removal Using the ANITA Mox Process: Pilot-Scale Evaluation at the Joint Water Pollution Control Plant (JWPCP)*, Proceedings of the WEFTEC '19, 92nd Annual Water Environment Federation (WEF) Technical Exhibition and Conference, Chicago, IL, Sept 21-25, 2019; Water Environment Federation: Alexandria, VA.

Onnis-Hayden, A; Majed, N; Li, Y; Rahman, S.M.; Drury, D.; Risso, L; Gu, A.Z. (2019) *Impact of solid residence time (SRT) on functionally relevant microbial populations and performance in fullscale enhanced biological phosphorus removal (EBPR) systems*, Water Environment Research, 92(3), 389-402. https://doi.org/10.1002/wer.1185.

USEPA.(2010) *Nutrient Control Design Manual.* U.S. Environmental Protection Agency, Washington, DC, EPA/600/R-10/100.

Membrane Bioreactor Fiber Cutting Protocol for Impaired Challenge Testing

Background

This protocol has been developed to better define the fiber cutting protocol to be enacted during evaluation of the membrane bioreactor (MBR) at the Advanced Purification Center (APC). Part of the intention of this protocol is to address an Independent Scientific Advisory Panel Comment regarding the need for more test details in order to address the comment: "*Membranes are backwashed and cleaned to address possible biofouling (implying biofilm features). The Panel believes the Project should consider variation in degree of biofouling with distance from the vacuum header when identifying fibers to cut. A standard operating procedure should be developed for fiber severing"*.

MBRs have typically demonstrated low filtrate turbidities (< 0.2NTU) and high log reduction value (LRV) of pathogens and indicators. The consistently low turbidity of operating facilities has made it difficult to define correlations between turbidity and LRV as the range of values is small and filtrate microorganisms are often below the limit of detection. Impaired fiber testing at the APC has two primary aims: 1) force filtrate turbidity to higher values to maximize the chance of developing useful correlations with LRV and 2) to investigate the sensitivity of both pressure decay testing (PDT) and filtrate turbidity to known levels of membrane damage.

Impaired Integrity Testing

The United States Environmental Protection Agency (USEPA) Membrane Filtration Guidance Manual (MFGM) (USEPA, 2005) specifically recommends fiber cutting studies to quantify the sensitivity of direct- and indirect- -integrity tests. In the APC context, a direct integrity test (DIT) will be the use of PDT and the indirect integrity test will be monitoring of MBR filtrate turbidity, as well as conducting pathogen sampling. Unfortunately, the MFGM provides little specific guidance with respect to fiber cutting studies, with the exception of recommending that "*Note that for many hollow fiber membrane filtration systems, cutting a fiber at the point at which it enters the potting material represents the most conservative condition"*(USEPA, 2005). In the Victorian Department of Health guidelines for validation of treatment processes, fiber cutting is also required during validation testing of micro- and ultra- filtration membranes for pathogen removal. In the Victorian validation guidelines, fiber cutting and the recommendation to cut as close as possible to the pot and report the distance is specified (VDoH, 2013).

The basis for damaging a fiber as close as possible to the module header can be explained by inspection of the Hagen-Poiseuille equation (Equation 1) that relates flow through a breach to: breach diameter and length, fluid viscosity and pressure differential (Antony, et al., 2014; Pontius, et al. 2011).

$$Q_{breach} = \frac{\pi d^4 (TMP)}{128 \mu L} \qquad \text{Equation 1}$$

Where: Q_{breach} *(m^3/s) is the flow through the breach, d(m) is the diameter of the breach, L(m) is the length of the breach, TMP(kPa) is the transmembrane pressure*

For a cut fiber d is the fiber internal diameter and L is effectively the distance between the fiber cut and the end of the module pot within the header. By inspection of Equation 1, it can be observed that Q is inversely proportional to L and proportional to TMP. This means that a worst case (high flow) breach should occur for a fiber cut as close to the pot as L is minimized.

While it may be interesting to conduct experiments to validate the correlation of Q_{breach} and length of fiber cutting, the goal of the impaired challenge testing is to develop an overall correlation of monitoring techniques with LRV. Also, cutting at different lengths from the pot does not correspond with recommendations from the USEPA MFGM and would likely not generate conditions of most concern to public health. As such, a systematic investigation of cutting at different lengths from is considered outside the scope of the study. But the lengths from the pot at which cuts are made could be measured and all cuts should be at a consistent location from the pot.

The panel indicate that biofouling may be an issue. Indeed, biofouling will increase TMP for the same net flowrate. At high levels of fouling, flow through a breach may also increase, according to Equation 1. In addition, the module closest to the filtrate pump will likely be under a marginally higher TMP than modules further away due to pressure losses further along the filtrate pipework. As a consequence, it is recommended to select modules that are as close as possible to the filtrate pump to be compromised, noting that modules as close as possible to the filtrate pump will represent the most conservative case. Also, it is recommended that during baseline testing and fiber cutting studies that in addition to filtrate turbidity, membrane flux (flow per unit area) and TMP are concurrently monitored.

Practical Issues with Fiber Cutting

Hollow fiber membrane modules, as employed at the APC, contains tens of thousands of individual fibers that are potted with resin into a module header at the top. The modules are coupled into racks, which are submerged in activated sludge. Filtration occurs through the walls of the hollow fiber into the central channel and is driven by means of a pump connected to the rack header. Figure 1 shows the activity of cutting a single fiber on a drinking water membrane during impaired challenge testing (a) and also older membrane modules that have been recently removed from a MBR (b).

a b

Figure 1 - a) Cutting a single fiber from a drinking water membrane and b) membrane modules that have been recently removed from an MBR.

From Figure 1 it can be observed that:

- Cutting single fibers is a delicate process and requires removal of the entire membrane rack and care not to unintentionally damage adjacent fibers.
- When MBR modules are removed they are typically covered in sludge and other debris that can make handling difficult.

The level of biofouling along the membrane length could be inferred if the membrane was systematically autopsied. However, an autopsy would need to be conducted after completion of the impaired challenge testing as the autopsy process is destructive. The difference in time between cutting fibers and eventual autopsy would introduce significant uncertainty into whether the autopsy results were representative of the fiber at the time of impaired testing. Accordingly, use of an autopsy to assess biofouling and its potential impact on impaired challenge testing is not recommended. The use of TMP monitoring is the most practical and non-destructive method for accounting for bulk biofouling levels experienced during the impaired membrane study.

Filtrate Disinfectant Residual from Backwashing

Membrane systems are periodically backwashed with sodium hypochlorite at effective concentrations of 100 - 300 mg/L to remove biofouling. Sodium hypochlorite at the concentrations used for backwashing would likely interfere with culture based virus and indicator microorganism analysis and may also impact quantification of *Giardia*, and to some extent *Cryptosporidium*. It will be important to ensure that either, 1) the sodium hypochlorite back flushes are not conducted during sampling or 2) a sufficient time is allowed to flush out chlorine residual before sampling begins. It is recommended that chlorine residual is checked and confirmed to be negligible at the start, during and the end of sampling to verify that there is no interference with pathogen and indicator analysis.

Suggested Fiber Cutting Procedure

Based on the information presented above, the following procedure is suggested for fiber cutting.

1. Conduct appropriate baseline testing with intact modules.
2. Select a module that is as close as possible to the filtrate withdrawal pump.
3. Conduct chemical cleaning on the membrane rack ideally within the week of challenge testing or closer to the day of challenge testing if TMP data indicates the system is fouling rapidly. Then, isolate the supply of sodium hypochlorite to the test racks.
4. Remove the membrane rack and gently hose rags and debris from the top portion.
5. Use a smooth thin rod to separate one fiber from the bundle and use a razor blade to cut the fiber as close as possible to the pot. It is typically difficult to cut at distances less than 6 inches from the pot without risking damage to other fibers.
6. Visually confirm that the fiber is cut cleanly.
7. Tie the bottom, longer portion, of the cut fiber closed to minimize any chance for solids carryover through the bottom section of the pot.
8. Reinstall the membrane rack.
9. Conduct a backwash.
10. Conduct a pressure hold test.
11. Put the membrane rack into service and commence sampling and monitoring.
12. During sampling monitor and record the following parameters.

   a. The PDT result immediately after cutting
   b. The online filtrate turbidity trend
   c. The online TMP trend
   d. The online Filtrate Flow and Membrane flux trend.
   e. Check the filtrate chlorine residual at the beginning, middle and end of the sampling cycle to ensure that there is no interference due to the presence of disinfectant.
13. Repeat steps 3 to 12 for each subsequent cut using the same module selected in step 2.

It is recommended to replace the damaged module with a new intact module before proceeding to the secondary MBR testing stage. If the damaged module is to be autopsied it should be wrapped in its original packaging, kept moist and cool. Ideally, the autopsy should be conducted as soon as possible after removing the module.

Anticipated results

- PDT results should respond quickly to cut fibers. If the cutting activity does not result in a noticeable increase in observed pressure decay rate it may mean that the fiber cutting was unsuccessful and a further fiber may need to be selected and cut.
- The filtrate turbidity will likely recover after cutting fibers. Recovery in as little as 15 minutes to nominal values has been noted in previous studies. Recovery can be assessed by monitoring the filtrate turbidity trend.

If desired, it may be possible to conduct replicate sampling events at the same level of damage by triggering a PDT and putting the unit into service. It is expected that the PDT will push out sludge flocs and re-open the plugged fiber.

References

Antony, A., Blackbeard, J., Angles, M., & Leslie, G. (2014). Non-microbial indicators for monitoring virus removal by ultrafiltration membranes. *Journal of Membrane Science*, *454*, 193-199.

Pontius, F. W., Crimaldi, J. P., & Amy, G. L. (2011). Virus passage through compromised low-pressure membranes: A particle tracking model. *Journal of Membrane Science*, *379*, 249-259.

USEPA. (2005). *USEPA Membrane Filtration Guidance Manual - Document number RPA 815-R-06-009.* Cincinnati, OH: US Environmental Protection Agency.

VDoH. (2013). *Guidelines for validating treatment processes for pathogen reduction - Supporting Class A recycled water schemes in Victoria.* Melbourne, Victoria, Australia: Victorian Department of Health.