Full-Scale Validation of Cryptosporidium and Giardia Log Reductions in Secondary Biological Treatment

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Reno, NV

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Reno, NV

Budget

Budget Requested from WE&RF	$49,810
Cash Contributions from Washoe County	$51,399
In-kind Services from Washoe County	$41,523
In-kind from Supporting Agency - TMWA	$24,935
Total Project Budget	**$167,667**

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Project Team

Washoe County Community Services Department, Reno NV
University of Nevada, Reno NV
Truckee Meadows Water Authority, Reno NV
IEH-BioVir Laboratories, Benicia CA
City of Reno, Reno NV
Truckee Meadows Water Reclamation Facility, Reno NV
EOA Inc., Oakland CA
James Crook, Water Reuse Consultant, Mattapoisett, MA

Research Objective

Establish reliable Cryptosporidium parvum oocysts (Crypto) and Giardia lamblia cysts (Giardia) log reductions (LRs) resulting from various configurations of secondary biological treatment to be utilized in future indirect potable reuse (IPR) projects in Nevada.

Technical Approach

Primary clarifier effluent or post-sedimentation raw wastewater (if there are no primary clarifiers) and secondary clarifier effluent samples (time-lag grab samples) will be collected for in-situ Crypto and Giardia quantification. Best suited sample pretreatment and quantification methods will be selected prior to the initiation of the actual sampling events. Data validation and QA/QC verification will be conducted throughout the project.

Originality and Innovation of the Research

Capitalizing on pathogen removal and/or inactivation provided by existing secondary biological treatment process eliminates the need for any additional treatment process and associated long-term costs. Considering the existing literature, it is critical to identify how a biological secondary treatment process must be designed and operated to reliably achieve 1 LR or greater for both Crypto and Giardia if Nevada DEP is to recognize specific types of secondary treatment processes as (1) being a Crypto and Giardia "barrier", and (2) providing 1 LR.

Relevance and Importance of this Research to WE&RF Subscribers

The proposed study will establish an additional treatment barrier for Crypto and Giardia removal/inactivation without additional costs by demonstrating LRs in specific types of existing secondary treatment processes. The proposed study will provide a cost effective IPR strategy without necessitating low pressure or high pressure membranes. The proposed strategy currently being investigated by the project team is more suitable for WRRFs located inland without oceanic discharge for RO reject disposal. The data collected from this research and the outcomes will have national implications for reclaimed water treatment train selection in IPR projects.

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3. Understanding of the Problem

Indirect Potable Reuse (IPR) is becoming an increasingly important and anticipated use of treated municipal wastewater in Nevada. Nevada Administrative Code (NAC) 445A.425 defines Category A+ (exceptional quality) standards as being suitable for IPR. Category A+ water must be treated by engineered and/or natural processes capable of achieving a 12-log enteric virus reduction, 10-log Giardia cyst reduction, and 10-log Cryptosporidium oocyst reduction. These pathogen reduction requirements are based on total log reduction achieved from the influent wastewater to the water resource recovery facility (WRRF) to the point of compliance (i.e., downstream of either the environmental buffer in the case of spreading basins or the last treatment process in the advanced water treatment train in the case of an injection well).

When an injection well is utilized for recharging groundwater, the wastewater being treated must pass through a minimum of three separate treatment processes (or barriers) for pathogen removal. A treatment process may be credited with a maximum of 6-LR and a minimum of 1-LR. For virus, the point of compliance is at the point of groundwater extraction for use. However, natural treatment by the saturated zone does not count for Crypto and Giardia reduction. Therefore, 10 LR of Crypto and Giardia must be achieved by at least three separate processes before the treated water is injection into the aquifer.

Crypto and Giardia LRs available from individual treatment options are presented below:

Candidate Treatment Processes for Crypto and Giardia LR	**Treatment Process Description**	**Crypto LR**	**Giardia LR**
Options widely utilized in drinking water and wastewater facilities	UV Disinfection or Advanced Oxidation Process (AOP)	6	6
	Membrane Filtration (MF)	4	4
Options typically utilized in drinking water facilities	Conventional Granular Media Filtration (GMF) with Coagulation, Flocculation, and Sedimentation Pretreatment	3	3
	Chlorine Dioxide	1	1-2
Options being considered by wastewater facilities	Secondary biological treatment	Varies	Varies
	Reverse Osmosis (RO)	Varies	Varies

Literature Related to Crypto and Giardia LR in Secondary Treatment

Crypto and Giardia LRs resulting from secondary biological treatment are not fully established. No Crypto and Giardia credits are awarded to secondary treatment in some cases due to a wide range of performance variabilities resulting from different types of secondary biological treatment processes.

Framework of Direct Potable Reuse (2015): Tables 7.4a and 7.4b (Pages 81 & 82) in the DPR (Direct Potable Reuse) Framework state that "No data exist that correlate secondary effluent water quality (e.g., BOD, turbidity, or TSS) with pathogen reduction. Data summarized in Table 6.2 (Page 59) indicate that log reductions of Crypto and Giardia in secondary treatment could be impacted by the nature of the treatment process (e.g., conventional activated sludge vs. activated sludge with biological nutrient removal).

Occurrence of Cryptosporidium, Giardia, and Cyclospora in influent and effluent water at wastewater treatment plants in Arizona (2014): Log reduction of Giardia cysts at a WRRF utilizing activated sludge (2 LR) was higher than at another WRRF using trickling filters (1.5 LR). No statistically significant difference between the two WRRFs was observed for the log reduction of Cryptosporidium oocysts (0.7 – 0.8 LR).

WERF Project 00-PUM-2T (2004): Operation of biological secondary treatment with longer mean cell residence times (MCRTs) tended to result in increased removal of bacterial indicators and pathogens. Increased virus removal was associated with biological nutrient removal and nitrification processes while removal of protozoan parasites was more variable. Log reductions of bacterial indicators were of similar magnitude to log reductions observed for enteric viruses and Giardia (total); however, reduction of Crypto did not parallel reduction of indicators.

Cost Impacts and Research Needs

Injection well IPR project proponents in Nevada have been considering a UV disinfection process for 6 LR and a filtration process for either 3 LR (Conventional GMF with pretreatment) or 4 LR (membrane filtration [MF]) of Crypto and Giardia. Within the filtration options, conventional filtration with pretreatment is preferred by the utilities due to its familiarity with the operations team and substantially lower lifecycle costs. A third barrier is necessary, even if the MF is installed. Rather than adding a whole new process to the WRRF, it is preferable to take 1 LR for Crypto and Giardia in the secondary treatment process, if said removal is reliably achieved. The literature suggests it is possible, but it needs to be demonstrated that secondary treatment can reliably provide required LRs under specific design and operational conditions.

The most cost effective "third barrier" options are either adding chlorine dioxide, or establishing that secondary treatment under specific design and operational conditions can reliably achieve 1 LR for both Crypto and Giardia. If 1 LR for both Crypto and Giardia resulting from secondary biological treatment process can be established, then it is estimated that a city with a WRRF flow of 1 MGD would save about $3,000,000 as illustrated in the table below.

Treatment Process	Relative Life Cycle Cost for 1 MGD ($)
Secondary Treatment (if validated for 1 LR)	$0 (already exists)
Chlorine Dioxide Disinfection with Contact Chamber (1 LR Crypto and 1+ LR Giardia)	$2,000,000

In summary, establishing 1 LR Crypto and Giardia credits in secondary biological treatment technically eliminates the need for any additional pathogen removal and/or inactivation step and provides several million dollars in savings.

4. Technical Approach

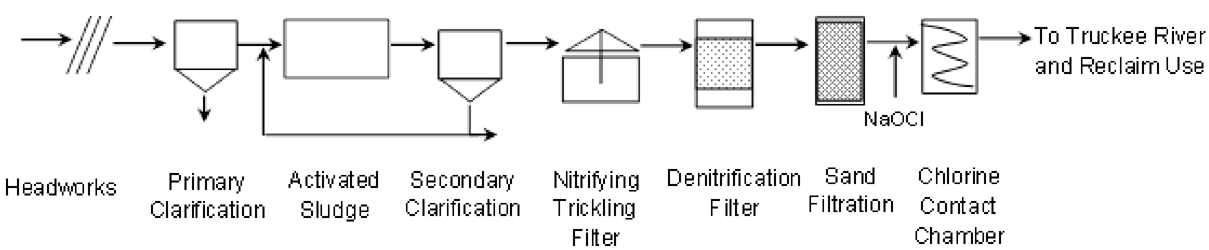
Task 1 Sampling and Validation Plan

The objective is to determine log reductions of Crypto and Giardia in secondary treatment under a wide range of conditions. The sampling plan involves all five major regional WRRFs in the Greater Reno Area which all use activated sludge treatment. Details of secondary treatment processes in the regional WRRFs are tabulated below:

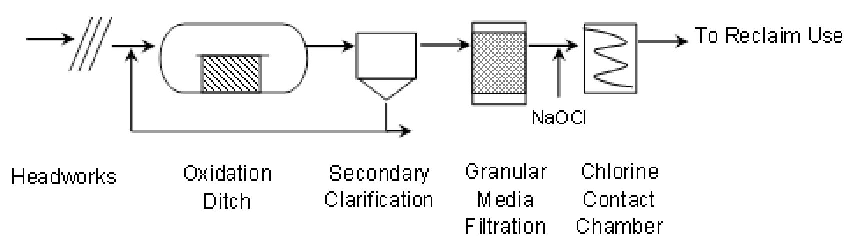
WWRF Name	Secondary Treatment Process
Truckee Meadows WRF (TMWRF)	Activated sludge achieving BOD Removal
South Truckee Meadows WRF (STMWRF)	Activated sludge achieving BOD Removal and simultaneous nitrification-denitrification
Reno-Stead WRF (RSWRF)	Activated sludge achieving BOD Removal, Nitrification, and Denitrification
Cold Springs WRF (CSWRF)	Activated sludge achieving BOD Removal and simultaneous nitrification-denitrification
Lemmon Valley WRF (LVWRF)	Activated sludge achieving BOD Removal

Process flow diagrams of these five WRRFs are presented below:

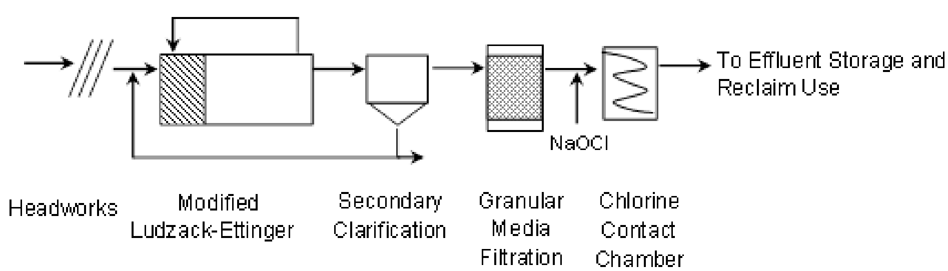
TMWRF:



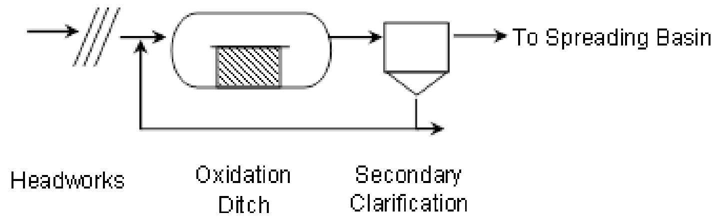
STMWRF:



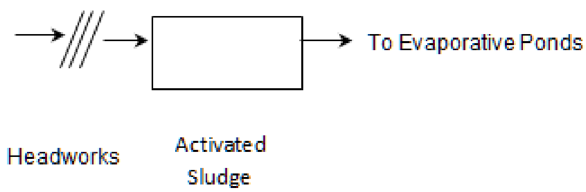
RSWRF:



CSWRF:



LVWRF:



The diversity in design and operational status of these five WRRFs is presented below:

	Plant Design Flow (mgd)	Average Flow (mgd)	Peaking Factor (Hour)	MCRT (days)
TMWRF	44	30	*	1.8-2.2
STMWRF	4.1	3	2.1	TBD
RSWRF	2.35	1.506	2.46	15-30
CSWRF	0.7	0.354	2.20	TBD
LVWRF	0.3	0.194	TBD	TBD

*Equalized/artificial headworks flow

This diversity coupled with sampling throughout a calendar year (hot to cold, dry to wet) provides credibility to the study results as being representative of reliable Crypto and Giardia removal by various types of secondary treatment under a wide range of design, flow, and climatic conditions.

Sampling Time Determination

Pathogen quantification methods typically require grab samples (with or without field filtration). Therefore, when the influent samples (and associated effluent samples) are collected is important. The best apparent time to collect influent samples for Crypto and Giardia are believed to be in the morning when the percentage of sanitary waste in the municipal wastewater is highest. To maximize the concentrations of Crypto and Giardia concentrations in the influent samples, each of the five WRRFs will be monitored seasonally for influent flow, pH, BOD, and electrical conductivity and the best apparent hour will be determined. The sample time determination step will be revisited during the course of the year-long monitoring campaign.

Sampling Methodology

Crypto and Giardia grab samples will be collected within a one-hour duration utilizing refrigerated flow-proportional composite samplers or Envirocheck filters (for filtered samples). A larger volume of secondary effluent samples could be collected and filtered in the filed utilizing Envirocheck filters. Effluent samples will be collected after a delay of time from the collection of influent samples. he time delay will be equal to the hydraulic retention time (HRT) of secondary treatment process (i.e., Effluent Time of Collection = Influent Time of Collection + HRT). HRT will be calculated based on the influent flow and the total volumes of aeration tanks and clarifiers (i.e., HRT = V/Q).

Quantification Method Determination and Matrix Spike Studies

Concurrent with the initial evaluation of sampling time, the appropriate EPA method(s) will be evaluated. EPA 1693 is a protozoa wastewater method that allows options in treating samples to optimize recovery (i.e., reduce method matrix interferences). EPA Method 1622/1623/1623.1 were developed for surface water analysis and not validated for wastewater, but may provide valuable information to this specific study. To determine the best suited method for the proposed project, a large volume of influent and effluent samples will be collected at the initial phase of the study for method determination. Each initial sample will be split into two parts and analyzed using surface water (Methods 1623) and wastewater (Method 1693) methods.

USEPA Methods for protozoa specify that at the beginning of a study and every 20^{th} sample, a matrix spike study should be conducted. In order to have a firmer grasp of concentration of Crypto and Giardia at the various sample points, it is critical that the study initially establishes recovery rates for each method/matrix and choose the best method for the specific matrix. The initial matrix spike studies will be conducted as part of the initial method determination step.

Sample Preparation (Field and Laboratory Steps)

For WRRFs without primary clarifiers, screened and degritted raw sewage samples will be taken to the UNR lab for bench-scale sedimentation simulating primary clarifiers prior to lab quantification. The lab sedimentation step is included to minimize quantification interferences related to particulates expected in the raw sewage. Additionally, the lab sedimentation step will enable side-by-side comparison of Crypto and Giardia removals observed in WRRFs with and without primary clarifiers.

Part of the foregoing work will be how to best concentrate the sample prior to analysis. This is particularly important with influent samples. An option is to centrifuge the sample, rather than filtering it directly. Removal of Crypto and Giardia from a filter may be 50 – 70% under best conditions. Therefore, introducing an intermediary step may further reduce recovery.

Split Sample Analysis

Because quantification of protozoa in wastewater matrices is difficult can be challenging, the proposed sampling and validation plan includes the splitting of samples between two labs (TMWA Lab, Reno NV and IEH-BioVir Laboratories, Benicia, CA) to determine the accuracy of a laboratory's analysis. Split samples allow a comparison of analytical results for two parts of the same sample from the same sampling location.

Additional Data Validation Steps

Additional data validation steps include field duplicates method specific ongoing precision and recovery (OPRs), and lab blanks; and unknown field-spiked samples sent to the labs. Infectivity studies are outside the scope of this proposed study.

Task 2 Field Sampling and Analysis

The proposed influent and secondary effluent field sampling schedule is presented in the table on the following page.

As shown, each of the five WRRFs will be sampled 4 times (i.e., quarterly), dispersed over one year. WRRF conditions will also be monitored and recorded for analysis with the Crypto and Giardia results. The WRRF conductions include:

- o Flow
- o Strength (BOC, TSS, pH, ORP, temperature, turbidity, total nitrogen, etc.)
- o Solids retention time (i.e., MCRT)
- o Seasonal variations
- o Performance variations (typically expected when a WRRF transitions from Winter to Spring, and Fall to Winter)
- o Diurnal variations

Task 3 Data Validation and Data Analysis

Rigorous data quality review will be conducted throughout the study. Final datasets will be reviewed for compliance with QA/QC criteria established in the validation plan. Acceptance and performance criteria will be selected based on the matrix spike results and compared to published method criteria reported in the literature.

Data validation and data analysis will be focused on meeting the following study goals:

- Estimating actual Crypto and Giardia presence in influent and effluent from both the field sample results and the percent recoveries from the matrix spike samples. Without this step to remove matrix interference from the field results to the extent feasible, it is not uncommon to conclude the secondary treatment actually increases the concentrations of Crypto and Giardia in wastewater.
- Estimating Crypto and Giardia removal ranges for secondary treatment.
- Evaluating the observed ranges in Crypto and Giardia removals as a function of various design, loading, operational, flow and climatic factors.

	Initial Method Determination Step	Month 1	Month 2	Month 3	Month 4	Month 5	Month 6	Month 7	Month 8	Month 9	Month 10	Month 11	Month 12	Total # of Samples per WRRF during the 12-month Monitoring Phase
TMWRF	**PE, SE**	PE, SE, Field DUP			PE, SE			PE, SE			PE, SE, Field DUP			**10**
STMWRF	**RWW, SE**			RWW, SE, Field DUP			RWW, SE			RWW, SE			RWW, SE, Field DUP	**10**
RSWRF	**RWW, SE (One of the three WRFs will be sampled)**		RWW, SE			RWW, SE, Field DUP			RWW, SE			RWW, SE, Field DUP		**10**
CSWRF			RWW, SE, Field DUP			RWW, SE			RWW, SE, Field DUP			RWW, SE		**10**
LVWRF				RWW, SE			RWW, SE, Field DUP			RWW, SE, Field DUP			RWW, SE	**10**
Data Validation Samples		TBD			TBD			TBD			TBD			**TBD**
Total # of Samples each month	**N/A**	**3+**	**5**	**5**	**2+**	**5**	**5**	**2+**	**5**	**5**	**3+**	**5**	**5**	**50+**

Legend:

RWW	Raw Wastewater
PE	Primary Effluent
SE	Secondary Effluent
Field DUP	Field Duplicate

Task 4 Report Preparation and NDEP Submission

The project team will prepare the draft and final reports to include 1) findings of initial method determination step, 2) presence of Crypto and Giardia in influent and effluent samples and percent recoveries observed from the matrix spike studies, 3) estimation of Crypto and Giardia removal across secondary treatment, and 4) findings on Crypto and Giardia removal as a function of WRRF conditions. The draft report will be submitted to WE&RF and to the Nevada Division of Environmental Protection (NDEP) for review and comments. The final report will be submitted to WE&RF for review and approval. The approved final report will be submitted to NDEP. The project team will submit a full research paper for publication in one of the leading peer-reviewed journal in wastewater/water reuse field.

5. Management, Communication, and Quality Assurance Plans

The proposed research team is highly qualified to complete the project. Besides practical experience as wastewater specialists and practitioners, the team has extensive experience in the US based regulatory frameworks, advanced engineering and operational practices, advanced water quality, chemical and microbial methods, their development and utilization of advanced statistical and risk assessment techniques.

Lydia Peri will serve as the Principal Investigator for the project and will dedicate 20% of her time. She will coordinate activities between the UNR, laboratories, Regional Stakeholders, and technical advisers. She will oversee the project budget and timeline, oversee sampling/analyses. She will also participate in data analysis and will contribute to the development of the final report. Ms. Peri will be responsible for communications with the project manager and Project Advisory Committee and will ensure all periodic reports are submitted in a timely manner.

Krishna Pagilla will serve as the co-Principal Investigator and the lead for the UNR research team and will dedicate 10% of his time. Dr. Pagilla will be responsible for research and sampling activities performed by UNR. He will participate in technical discussions and will manage UNR staff for this project.

Jim Crook and Adam Oliveri will serve as the external technical advisory committee. The technical advisory committee will be involved in reviewing draft plans before the initiation of the project, reviewing results from initial method determination, participating in the selection of the best suited method, reviewing field sampling results, participating in data validation activities, and reviewing draft and final reports.

Rick Warner and John Enloe will serve as the stakeholder representatives and technical advisors. Mr. Warner and Mr. Enloe will be responsible for communicating the study progress and results to Regional Agencies in Reno and to Nevada Division of Environmental Protection.

Vijay Sundaram will lead the day-to-day activities of the project for UNR and will dedicate 30% of his time during sampling events. Mr. Sundaram will work on preparation of sampling and validation plans, initial sampling for method determination, method selection, evaluating WRRF conditions, field sampling, data analysis, data validation, preparation of draft and final reports.

Rick Danielson will lead the Crypto and Giardia quantification team at IEH-BioVir laboratory. Dr. Danielson will provide guidance on field sampling methods and other QA/QC steps. Dr. Danielson has past experiences working with Crypto and Giardia quantification in the wastewater matrix and therefore will offer strategies on the variations of sampling methods to optimize recovery for a given matrix.

Communications

Regional Communication: During the execution of the project, the project team will routinely communicate the progress of the project with Regional Agencies in Reno. Communications with NDEP will be handled by stakeholder representatives. NDEP will receive the sampling and validation plan prior to the initiation of the field sampling, and draft/final reports.

WE&RF Communication: The project team will host a webinar sponsored by WE&RF at the completion of the project. Abstracts will be submitted for WateReuse Annual Conference, WateReuse Research Conference, and WEFTEC.

Peer-Reviewed Article: The project team will submit a full research paper for publication in one of the leading peer-reviewed journals (water research or water environment research) in the wastewater/water reuse field.

Quality Assurance Plans (QAP)

Due to space limitation, the QAP is only discussed briefly in this section. Both TMWA lab and BioVir Lab are certified laboratories, have an extensive QA/QC program and will be responsible for the Crypto and Giardia analyses. While it is anticipated that the water quality analyses (e.g. pH, turbidity, temperature, conductivity, ORP etc.) will be performed by WRRFs at the time of sample collection, additional verification of these data will be performed via external water quality laboratories, as needed.

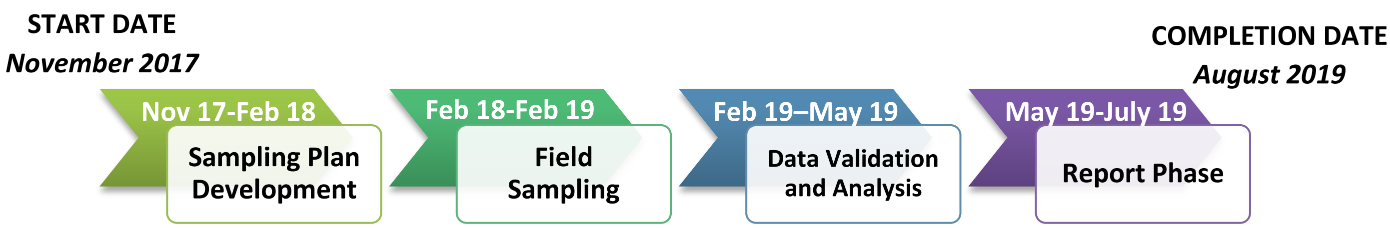
Based on the lessons learned on the quantification of Crypto and Giardia in wastewater, the project team has proposed an initial method determination step including matrix spike studies to determine recovery rates. Best suited methods for this each matrix will be determined based on this step.

Specific QA/QC steps during field sampling include: 1) split samples sent to TMWA and BioVir labs, 2) field duplicates (10-20% of total field samples will be allocated of QA/QC), 3) method specific OPRs, 4) lab blanks, and 5) unknown field-spiked samples. The QA/QC plans for these sampling events and laboratory analyses will include specific details on reagents, glassware for analyses and water sample collection, sample handling, identification, preservation, transportation, and storage analytical parameters, requirements for precision, accuracy, representativeness, completeness, comparability, data reduction, reporting, and statistics.

6. Schedule and Deliverables

The project will start on 11/15/2017 and the various tasks, specified in the proposal, will be performed over a period of 20 months. The team is highly experienced with the proposed tasks. As almost all the samples will be collected at full-scale WRRFs, no delays in starting the project are anticipated. It is anticipated that Task 1b (Method Determination) will require 3 months for completion and preparation will begin immediately. Simultaneously, the WRRFs participating in Task 2 (Field Sampling) will be contacted in the first quarter. To capture seasonal effects, sampling (Task 2) will be conducted in each of the four quarters and laboratory based Crypto and Giardia quantification work will be conducted over a 12 month period. Task 3 (Data Validation and Data Analysis) will be performed concurrently to Task 2 with analysis on full dataset occurring after the completion of Task 2. Draft and final project report preparation will be initiated concurrently with Task 3 and scheduled to be completed by the third quarter of 2019. It is anticipated that draft report will be submitted to WE&RF in the third quarter of year 2. The final report will be submitted before the end of month 20. Periodic progress reports will be submitted at quarterly intervals throughout the 20 month duration of this project. PAC calls or meetings will be coordinated through the WE&RF project manager.

Project Duration	**20 months**
Sampling and Validation Plan Development	3 months
Field Sampling and Analysis	12 months
Data Validation and Analysis	3 month
Report Preparation and NDEP Submission	2 months



7. Budget

BioVir and TMWA Lab Analysis Cost

	Cost/sample	# of samples	Total Cost
Initial Method Determination Step			
EPA 1693 Wastewater	360	6	2,160
EPA 1623 Effluent	350	6	2,100
Matrix Spike	425	6	2,550
			6,810
12-month Monitoring Step			
EPA 1693 Wastewater (to be confirmed during method determination step)	360	25	9,000
BioVir Analysis Total			**15,810**
TMWA Analysis Total	250	50	**12,500**

The full budget is listed on the following page. In kind water quality analysis will be comprised of wastewater facility sampling that compliments this project. This project will request water quality analysis from each facility including, but not limited to, TSS, BOD, Ammonia, etc. as in kind service. The Truckee Meadows Water Authority has committed to in kind sample analysis of up to 50 samples as well as in kind service of laboratory technicians. Mr. Enloe of TMWA will also commit to in kind service as he will serve on the technical committee (see attached letter of support from Mr. Enloe).

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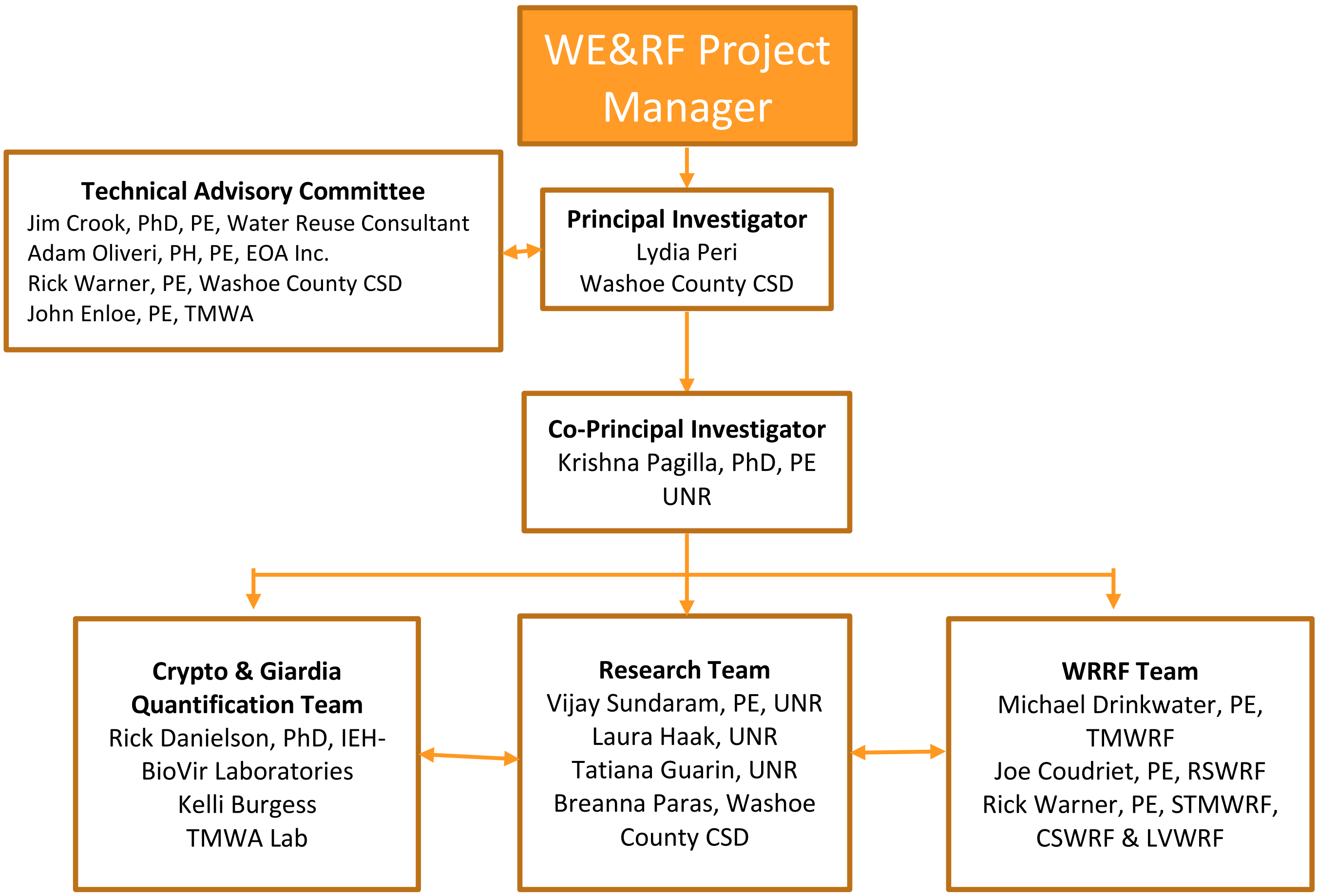
Personnel (Washoe County)								
Name	Project Role	Hours	Rate ($/hour)	Fringe Benefits ($/hr)	Total Cost	WC Cash Funding	In-Kind (service)	WE&RF Funding
Lydia Peri	PI-overall coordination, management	200	33.29	13.44	9,346.00		9,346.00	
Rick Warner	Adviser, WE&RF Coordination	80	53.54	23.55	6,167.20		6,167.20	
Breanna Paras	Sampling	100	12.60	0.00	1,260.00		1,260.00	
				Subtotal	**16,773.20**	**0.00**	**16,773.20**	**0.00**
Other Direct Costs					Total Cost	WC Cash Funding	In-Kind	WE&RF Funding
Equipment								
Sample Shipping Cost (lump sum; partial)					3,250.00		3,250.00	
Water quality analyses					12,500.00		12,500.00	
Influent and Effluent Samplers					25,000.00	20,000.00	5,000.00	
				Subtotal	**40,750.00**	**20,000.00**	**20,750.00**	**0.00**
Supplies								
Sampler supplies (tubing, sample jars, etc.)					1,000.00		1,000.00	
				Subtotal	**1,000.00**	**0.00**	**1,000.00**	**0.00**
Subcontracts								
IEH BioVir Laboratories					15,810.00			15,810.00
TMWA Laboratories - In Kind TMWA					12,500.00		12,500.00	
Krishna Pagilla	UNR Lead	40	133.51	35.57	6,763.08	6,763.08		
Vijay Sundaram	PhD Student	300	33.33	5.76	11,726.83	11,726.83		
Laura Haak	PhD Student	100	27.50	4.75	3,225.20	3,225.20		
Tatiana Guarin	MS Student	250	22.50	3.89	6,597.00	6,597.00		
UNR Intern(s)	BS Student(s)	250	12.00	0.35	3,086.40	3,086.40		
James Crook	Adviser	40	250	-	10,000.00			10,000.00
Adam Oliveri	Adviser	40	250	-	10,000.00			10,000.00
Rick Danielson	Adviser	40	200	-	8,000.00			8,000.00
John Enloe	Adviser	80	79.06	38.75	9,424.80		9,424.80	
Kelli Burgess	TMWA Lab	40	50.36	24.90	3,010.40		3,010.40	
Travel (Subcontractors)					6,000.00			6,000.00
				Subtotal	**106,143.71**	**31,398.51**	**24,935.20**	**49,810.00**
Disadvantaged Business								
				Subtotal	0	0	0	0
Travel								
Washoe County CSD Team					3,000.00		3,000.00	
				Subtotal	**3,000.00**	**0.00**	**3,000.00**	**0.00**
				TOTAL	**$ 167,667**	**$ 51,399**	**$ 66,458**	**$ 49,810**

8. Letters of Support, Qualifications, Résumés, Organizational Charts, References, and Technical Resources



Lydia Peri,

Washoe County

Lydia Peri is an Environmental Engineer with the Washoe County (Nevada) Community Services Department. Lydia earned a bachelor's in ecohydrology from the University of Nevada, Reno in 2011 and earned a dual master's in hydrogeology and civil and environmental engineering in 2015 also from the University of Nevada, Reno. She recently accepted a position as a Ph.D. candidate in the Environmental Engineering Program with Dr. Krishna Pagilla at the University of Nevada, Reno. Her work with the University will primarily focus on the hydrogeologic investigations for the Northern Nevada potable reuse initiative. Lydia is actively engaged with the Water Environment Federation on the Water Reuse Committee. She is also an active member with several local community volunteer groups. As a graduate student, Lydia spent time in Panama constructing composting latrines and also worked in Kenya building ferro cement rainwater catchment tanks. In 2015, she was awarded Outstanding Young Alumnus of the Year by the University of Nevada Alumni Association.

Krishna Pagilla, Ph.D., P.E., BCEE

University of Nevada, Reno

Krishna Pagilla, Ph.D., P.E., BCEE is a Professor and Environmental Engineering Program Director at the University of Nevada, Reno. Prior to relocating to Reno, Prof. Pagilla was a professor of Environmental Engineering at the Illinois Institute of Technology and is a licensed engineer in California and Illinois. He has over 20 years of experience in teaching and research and has published extensively including 75 peer reviewed journal papers and over 100 other papers/reports. Prof. Pagilla has leadership roles in the environmental engineering profession. He is an Associate Editor of Water Environment Research and is a Fellow of both Water Environment Federation (WEF) and International Water Association (IWA). He has received numerous awards for his work including the Harrison Prescott Eddy Medal from WEF in 2011 and Bill Boyle Outstanding Education Award from the Central States Water Environment Association.

Rick Danielson, PhD

IEH-BioVir Laboratories

Rick E. Danielson, Ph.D., Vice President and Laboratory Director, has worked for over 30 years in the field of environmental health microbiology. His multi-faceted career has covered Biotechnology (PCR, ELISA, plasmid analyses), microbial risk assessment, environmental virology, and parasitology.

In addition to a staff headed by these veteran scientists, BioVir has a close association with experts in various fields of medical and environmental microbiology who consult on special projects.

Adam Olivieri, Dr.PH, P.E.

Potable Reuse – Public Health and Regulatory Strategy

Adam has over 35 years of experience in the technical and regulatory aspects of water recycling, groundwater contamination by hazardous materials, water quality and public health risk assessments, water quality planning, wastewater facility planning, urban runoff management, and on-site waste treatment systems. He has gained this experience through working as a staff engineer with the California Regional Water Quality Control Board (San Francisco Bay Region), as staff specialist (and Post-doc fellow) with the School of Public Health at the University of California, Berkeley, project manager/researcher for the Public Health Institute, and as a consulting engineer. He is currently the Vice president of EOA, Inc., where he manages a variety of projects, including serving as Santa Clara County Urban Runoff Program's Manager since 1998. Adam has served on numerous expert panels and advisory committees regarding public health aspects of recycled water use. He is also the author or co-author of numerous technical publications and project reports.

James Crook, Ph.D., P.E.

Water Reuse and Environmental Engineering Consultant (Boston, MA)

Jim Crook is an environmental engineer with more than 40 years of experience in state government and consulting engineering arenas, serving public and private sectors in the U.S. and abroad. He has authored more than 100 publications and is an internationally recognized expert in water reclamation and reuse. He has been involved in numerous projects and research activities involving public health, regulations and permitting, water quality, risk assessment, treatment technology, and all facets of water reuse. Crook spent 15 years directing the California Department of Health Services' water reuse program, during which time he developed California's first comprehensive water reuse criteria. He also spent 15 years with consulting firms overseeing water reuse activities and is now an independent consultant specializing in water reuse. He currently serves on several advisory panels and committees sponsored by NWRI and others. Among his honors, he was selected as the American Academy of Environmental Engineers' 2002 Kappe Lecturer and the WateReuse Association's 2005 Person of the Year. Crook received a B.S. in Civil Engineering from the University of Massachusetts and both an M.S. and Ph.D. in Environmental Engineering from the University of Cincinnati.

Rick Warner, P.E.
Washoe County

Rick Warner, P.E. is the 2016-17 President of the Water Environment Federation (WEF), and presently serves on the Board of Directors of the Water Environment and Reuse Foundation. In addition, he is a senior engineer for the Washoe County (Nevada) Community Services Department. In that role he is responsible for planning, design, and construction for regional water resource recovery and recycled water projects. Rick is actively engaged with several water reuse projects, and is presently co-leading a regional team developing Nevada's first potable reuse project. Rick is a member of the WateReuse Association, the Water Environment and Reuse Foundation, and the Design Build Institute of America. Mr. Warner is presently collaborating with Dr. Krishna Pagilla, Professor and Environmental Engineering Program Director at the University of Nevada, Reno to create a Water Innovation Campus – an effort to advance water science and technology for municipal, industrial, and agricultural applications while enhancing the economic, social, and environmental aspects of the water environment. Rick is a registered professional engineer in the state of Nevada. He received a B.S. and an M.S. in civil engineering from the University of Nevada.

Vijay Sundaram, P.E.
University of Nevada, Reno

Vijay Sundaram, P.E. leads the Stantec water reuse technology practice and is Stantec's national technical lead for water regulations and compliance. Vijay has well-rounded experience in designing and evaluating processes for municipal and industrial water and wastewater treatment, including work with advanced treatment, water recycling, and energy optimization. From 2008 – 2011, Vijay was project engineer-in-charge of developing and implementing an energy efficient innovative advanced treatment process for the City of Reno, which includes (in order of use): membrane or granular media filtration, ozone oxidation, and biologically active carbon (BAC) filtration. He has authored several technical articles on sustainable water reuse and advanced treatment processes. Currently, Vijay is Co-Principal Investigator in conducting Ozone-BAC research that will result in an operational guidelines document designed to be sufficient for widespread implementation of the Ozone-BAC technology for potable reuse.

John Enloe, P.E.
Truckee Meadows Water Authority

John Enloe directs the planning and management activities of the Truckee Meadows Water Authority's lands, well development, groundwater and surface water rights and forecasting/future resource planning. Mr. Enloe has over 30 years of water planning, permitting, design, project implementation, operations and business management experience in the Reno / Lake Tahoe community. Mr. Enloe also brings considerable local expertise in regional wastewater, reclaimed water, water quality and effluent-disposal-management issues. This diverse experience provides a comprehensive "big picture" understanding of the complex water issues facing the Truckee Meadows.

Mr. Enloe holds a Bachelor of Science degree in Environmental Engineering, and is a registered professional Civil Engineer in Nevada and California. His experience includes 17 years running a successful consulting practice in Reno, including 5 years of leadership training for small business CEOs.

References

Kitajima, M., Haramoto, E., Iker, B.C., Gerba, C.P., (2014) Occurrence of Cryptosporidium, Giardia, and Cyclospora in influent and effluent water at wastewater treatment plants in Arizona, Science of Total Environment, 484, 129-136.

Rose, J.B., Nowlin, H., Farrah, S.R., Harwood, V., Levine, A., Lukasik, J. Menendez, P. & Scott, T.M., (2004) Reduction of Pathogens, Indicator Bacteria, and Alternative Indicators by Wastewater Treatment and Reclamation Processes. Water Environment Research Foundation Report 00-PUM-2T, Alexandria, VA.

WateReuse Research Foundation (2015) Framework for Direct Potable Reuse.