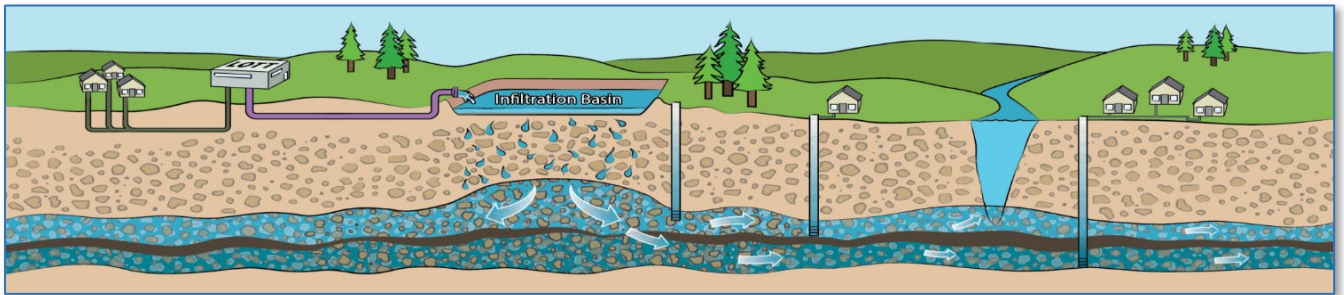


# Cost Benefit Analysis (Task 4)

## LOTT Clean Water Alliance Reclaimed Water Infiltration Study

### Technical Memorandum

AUGUST 9, 2022



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## Key Acronyms and Abbreviations

|       |                                     |
|-------|-------------------------------------|
| BAC   | biologically activated carbon       |
| BIRWP | Budd Inlet Reclaimed Water Plant    |
| ERA   | Ecological Risk Assessment          |
| GAC   | granular activated carbon           |
| HHRA  | Human Health Risk Assessment        |
| LOTT  | LOTT Clean Water Alliance           |
| mgd   | million gallons per day             |
| MWRWP | Martin Way Reclaimed Water Plant    |
| NDMA  | N-Nitrosodimethylamine              |
| PFAS  | per- and polyfluoroalkyl substances |
| PFPeA | perfluoropentanoic acid             |
| PV    | present value                       |
| RME   | Reasonable Maximum Exposure         |
| RO    | reverse osmosis                     |
| RWIS  | Reclaimed Water Infiltration Study  |

# 1.0 Introduction

This technical memorandum documents the methodology and results of a cost benefit analysis of reclaimed water treatment options, in the context of the LOTT Clean Water Alliance (LOTT) Reclaimed Water Infiltration Study (RWIS).

## 1.1 Background

LOTT provides services to treat and manage wastewater for the urban areas of Lacey, Olympia, and Tumwater in Thurston County, Washington (at the southern end of Puget Sound). Since 2006, LOTT has also produced reclaimed water at the Budd Inlet Reclaimed Water Plant (BIRWP) and Martin Way Reclaimed Water Plant (MWRWP) for irrigation and other non-drinking purposes. Some of the reclaimed water produced at the MWRWP is used to recharge (replenish) groundwater using rapid-infiltration basins on the LOTT Hawks Prairie Reclaimed Water Ponds and Recharge Basins (Hawks Prairie property). The long-range plan for meeting future wastewater management needs includes expanding reclaimed water production and developing additional groundwater recharge facilities.

LOTT is conducting the RWIS to provide local scientific data and community input to help policymakers make informed decisions about future reclaimed water treatment and use. Residual chemicals are the primary focus of the study; these include household chemicals, pesticides/herbicides, pharmaceuticals, personal care products, cooking products, and flame retardants. LOTT is evaluating which of these residual chemicals remain in reclaimed water after treatment, which exist in the local environment, how infiltrated reclaimed water interacts with soils and local groundwater, and what happens to the residual chemicals over time in the environment. LOTT and the wider community will use the findings of the study to make the most appropriate choices for reclaimed water management and protection of public health and the environment.

The study components include (bolded for the current task described in this document):

- Surface water, groundwater, and reclaimed water quality monitoring to determine water quality and evaluate occurrence and concentration of residual chemicals.
- Tracer testing at the LOTT Hawks Prairie property to identify dominant downgradient flow paths and travel times to monitoring wells as reclaimed water infiltrates the vadose zone to the water table and is then transported by groundwater.
- Groundwater flow and particle tracking modeling to estimate flow paths and travel time beyond the spatial and temporal extent identified through tracer testing and at a variety of recharge rates typical of future operational capacity of the reclaimed water recharge facility at Hawks Prairie.
- Fate and transport groundwater modeling to estimate residual chemical concentrations to downgradient receptors at current and future reclaimed water aquifer recharge rates.
- Risk assessment to understand potential human health and ecological risks posed by replenishing groundwater with reclaimed water.

- **Cost/benefit analysis of various options for reclaimed water treatment and identification of other potential actions to address residual chemicals in reclaimed water.**

## 1.2 Technical Memorandum Contents

Task 4 of the RWIS includes developing implementation costs for various reclaimed water treatment approaches and uses, which are then used to prepare a cost/benefit analysis of options that weigh such treatment/use costs against their associated benefits in terms of human health and ecological risk reduction. LOTT currently produces Class A reclaimed water at both its Budd Inlet Reclaimed Water Plant (BIRWP) and Martin Way Reclaimed Water Plant (MWRWP). One of the objectives of Task 4 is to consider additional treatment trains that, if added to the current Class A treatment processes, would increase the removal efficiencies of residual chemicals that passed through the human health and ecological screening level risk evaluations and have been evaluated in more detail in the subsequent risk assessments (i.e., the work conducted in the Human Health Risk Assessment [HHRA] and Ecological Risk Assessment [ERA] in Task 3 of the RWIS<sup>1</sup>).

A previous memorandum (provided in Appendix A) documents an analysis of various treatment trains and their effectiveness in removing select residual chemicals from reclaimed water. The result of that effort was identification of two advanced treatment trains for further consideration: one based on reverse osmosis (RO), and one utilizing non-RO technologies. In addition, that analysis presented options for targeted treatment of N-nitrosodimethylamine (NDMA) and perfluoropentanoic acid (PFPeA), as these two chemicals are the only ones identified in the HHRA as potentially being present at exposure point concentrations that may result in risk thresholds being exceeded.

This technical memorandum summarizes conceptual-level cost estimates developed for these previously-identified treatment trains and the targeted treatment option. The costs and benefits, in terms of reduced risk levels, are then compared amongst the options as they relate to the use of reclaimed water for groundwater recharge. The memorandum also identifies items to consider in a broader analysis of potential actions to address residual chemicals in reclaimed water. This analysis will be developed more fully as part of LOTT's long-range master planning efforts, as it pertains more comprehensively to LOTT's resource management strategy.

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<sup>1</sup> The risk assessments are documented in the following reports:

HHRA: *Human Health Risk Assessment – LOTT Clean Water Alliance Reclaimed Water Infiltration Study*. Intertox, Inc. June 20, 2022.

ERA: *Ecological Risk Assessment – LOTT Clean Water Alliance Reclaimed Water Infiltration Study*. Windward LLC. June 20, 2022.

## 2.0 Residual Chemicals of Interest

Out of the residual chemicals that were detected in reclaimed water in at least one sampling event during execution of Tasks 1 and 2 of the RWIS, below is the subset of chemicals that were initially identified in the Task 3 (risk assessment) work as being of potential concern from a human health / ecological risk perspective:

- 1,4-Dioxane
- 4-Nonylphenol
- Carbamazepine
- Fipronil
- N-Nitrosodimethylamine (NDMA)
- Primidone
- Quinoline
- Per- and polyfluoroalkyl substances (PFAS)

The results of the risk assessment work can be summarized as follows:

- **Human Health Risk Assessment.** The HHRA concluded that the potential for residual chemicals currently present in reclaimed water infiltrated into groundwater to cause risk to human health assessment endpoints is low. Two chemicals were identified as potentially being present at concentrations that exceed minimum risk thresholds:
  - PFPeA. Estimated upper bound noncancer hazard indices (HIs) exceed the minimum threshold level of concern of 1.0 for only one chemical—PFPeA—for the Reasonable Maximum Exposure (RME) child resident scenario, with an estimated HI of 1.3. The RME scenario is intended to reflect a high end estimate of potential exposures. It is defined as the highest exposure that is reasonably expected to occur at a site, and is intended to estimate a conservative exposure case (i.e., well above the average case). As discussed in the HHRA, an HI >1 does not mean that adverse health effects are expected or will occur. In fact, if the HI is close to 1 (as is the case for the upper bound noncancer hazard estimate for the RME child resident scenario for PFPeA), adverse health effects are unlikely even if a person's exposure is at this estimated upper bound level. This is because multiple uncertainty factors are incorporated into the derived allowable daily dose for this chemical that is used to calculate the noncancer hazard, to ensure it is at a level at which health effects are not expected.
  - NDMA. Estimated upper bound lifetime excess cancer risks (LECRs) exceed the *de minimis* cancer benchmark of 1 in 1,000,000, or  $10^{-6}$  for only one chemical—NDMA—for the RME resident scenario, which has an estimated LECR of  $2.9 \times 10^{-6}$ . As discussed in the HHRA, while the upper bound LECR estimate for the RME resident scenario slightly exceeds a *de minimis* one-in-a-million LECR, it falls within the range of risks considered to be allowable by U.S. EPA and others at different sites depending on specific site characteristics ( $1 \times 10^{-4}$  to  $1 \times 10^{-6}$ , or 1 in 10,000 to 1 in 1,000,000).

Further detail and interpretation regarding the HHRA results, including discussion of a probabilistic risk assessment that was conducted for these two chemicals for the RME resident scenario can be found in the HHRA document.

- ***Ecological Risk Assessment.*** The ERA concluded that the potential for residual chemicals currently present in reclaimed water infiltrated into groundwater to cause risk to ecological assessment endpoints is negligible, as exposure point concentrations for chemicals of interest were far below levels of concern.

These results of the risk assessment informed the final definition of additional treatment train options for consideration (discussed in Section 3) and the comparison of costs to benefits (discussed in Section 5).

## 3.0 Treatment Trains

The Task 4 scope of work envisioned considering an RO based treatment train and a non-RO option. Literature research emphasized that instead of using a single non-RO treatment option, a combination of other treatment options would provide a multiple-barrier system that would prove to be just as effective in removing most, if not all, residual chemicals. The combined treatment train of Ozone-Biologically Activated Carbon-Granular Activated Carbon (Ozone-BAC-GAC) was selected as the most effective multiple barrier non-RO system that removes residual chemicals, with a special emphasis on PFPeA and NDMA. Appendix A provides documentation of the literature review pertaining to treatment process definition and expected removal efficiencies.

Further simplification of the non-RO treatment train is possible if the primary focus is to remove PFPeA (and other PFAS), and potentially NDMA, to the extent possible. In this case, the non-RO treatment train is simplified to be GAC treatment alone. GAC is highly effective in removing PFAS, and although it only sparingly adsorbs the NDMA molecule itself<sup>2</sup>, it has been shown to effectively reduce the formation potential of NDMA by greater than 90 percent by removing NDMA precursors. As is discussed in more detail in Appendix A, it is currently unknown to what extent NDMA is present in influent wastewater to LOTT's treatment facilities, versus how much NDMA may be formed as a result of the disinfection process. Therefore, more characterization is required to determine the effectiveness of GAC treatment on NDMA in LOTT's reclaimed water.

Table 1 provides a summary of removal efficiencies for LOTT's current reclaimed water treatment processes, as well as the three treatment trains summarized above. Appendix A provides additional detail regarding the effectiveness of various treatment approaches on removing specific chemicals and provides references for the literature reviewed to inform the values in the table.

For each of the three advanced treatment options considered, cost estimates were derived for two facility sizes: 1 million gallons per day (mgd), which reflects the approximate current amount of reclaimed water that is produced and used for groundwater recharge; and 5 mgd, reflecting a long-range potential future capacity of the facility.

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<sup>2</sup> Kommineni, S., Ela, W. P., Arnold, R. G., Huling, S. G., Hester, B. J., & Betterton, E. A. (2003). NDMA treatment by sequential GAC adsorption and Fenton-driven destruction. *Environmental engineering science*, 20(4), 361-373.

**Table 1. Removal Efficiencies for Potential Treatment Trains**

| <b>Residual Chemical</b> | <b>Existing Class A Reclaimed Water Treatment % Removal (BIRWP / MWRWP) <sup>a</sup></b> | <b>RO/RO-AOP % Removal (Treatment Train 1)</b>   | <b>Ozone-BAC-GAC % Removal (Treatment Train 2)</b> | <b>GAC only % Removal (Treatment Train 3)</b> |
|--------------------------|------------------------------------------------------------------------------------------|--------------------------------------------------|----------------------------------------------------|-----------------------------------------------|
| 1,4-Dioxane              | NC / NC                                                                                  | 75-83<br>(RO-UV/ H <sub>2</sub> O <sub>2</sub> ) | 50-73                                              | 18-30                                         |
| 4-Nonylphenol            | 72 / 77                                                                                  | 85-95<br>(only RO)                               | 99                                                 | >85                                           |
| Carbamazepine            | 32 / 34                                                                                  | >95<br>(only RO)                                 | 97.5                                               | 24-62                                         |
| Fipronil                 | NC / NC                                                                                  | >95<br>(only RO)                                 | 74-100                                             | 40                                            |
| NDMA                     | 12 / 57                                                                                  | 62-98<br>(RO-UV/ H <sub>2</sub> O <sub>2</sub> ) | 70-94.4                                            | 60-90 <sup>c</sup>                            |
| Primidone                | 38 / NC                                                                                  | >98<br>(only RO)                                 | 96                                                 | 51                                            |
| Quinoline                | 88 / 85                                                                                  | >90<br>(only RO)                                 | 85-95                                              | 93-98                                         |
| PFAS                     | 62 / NC <sup>b</sup>                                                                     | >99<br>(only RO)                                 | 95-99                                              | >95                                           |

**Notes:**

See Appendix A for reference citations from which these removal efficiencies were obtained.

- Percentage (%) removal indicates the average removal calculated from all RWIS Task 1 sampling events (from November 2014 to August 2015) at the BIRWP and MWRWP. "NC" indicates Not Calculated (due to the chemical not being detected in raw wastewater or detected in raw wastewater at a value lower than that in reclaimed water, therefore resulting in a negative % removal efficiency).
- The only calculated PFAS removal value is for perfluoropentanoic acid. The data from one sampling event at the BIRWP yielded this result. In the case of all other PFAS chemicals analyzed, the result was "NC", per the above footnote.
- Predicated on removal of NDMA precursors, thereby preventing formation of NDMA during disinfection. Removal of the NDMA molecule via GAC is minimal.

## **4.0 Conceptual Level Cost Estimates**

The following sections present an Opinion of Probable Project Cost (OPPC) for project implementation, along with ongoing annual system operation and maintenance (O&M) costs for each option. Details regarding the cost estimates for each option are presented in Appendix B.

### **4.1 Approach and Assumptions**

The OPPCs were developed using an American Association of Cost Engineers (AACE) process, wherein a base cost for the project was developed and a reasonable range was then applied to that base cost to identify the expected cost range for the project.

The base costs are derived from cost data developed from CostSpace, an internal HDR planning level cost estimating tool used for evaluating treatment process options and determining capital, operating and life cycle costs. Furthermore, previous projects and cost factors from generally accepted sources such as vendor quotes and recently bid construction projects were also used to inform the OPPCs.

The OPPCs include the following items:

- Anticipated construction cost
- Engineering fees for planning, design, and construction administration
- Internal legal and administrative costs
- Project contingency funds

The OPPCs are presented in January 2022 dollars and have not been escalated to a potential date of construction. Care should be taken to escalate these costs based on the actual date of construction.

### **4.2 Class of Opinion of Probable Project Cost**

The AACE has defined different classes of OPPCs in an effort to establish the expected accuracy range for various types of cost estimates. The appropriate class is based on the project status and level of development. The OPPC presented in this report is considered a Class 5 estimate, which provides an expected accuracy of +100% to -50%.

The cost range is intended to cover the following items:

- Unknown bid environment at the time the project goes out to bid
- Reasonable refinement in material unit quantities as the project design advances and is further refined

The range is not intended to cover significant changes to the conceptual design or scope that may occur during advancement of the project.

### **4.3 Capital Cost Contingencies and Allowances**

Planning-level cost estimates are not precise due to the conceptual nature of design at this stage of project development. To address this, contingencies are added to account for the

increased level of uncertainty. In addition to a wide range of project contingencies, allowances are included to account for other associated project costs, such as engineering, legal, and administrative costs, to provide an opinion of total project cost, not just construction cost.

The following contingencies and allowances were included for all OPPCs, as identified in Table 2. In addition, it is noted that space availability at existing facility locations has not been evaluated and there is a potential need for additional land to be purchased to accommodate these treatment trains. Costs associated with land acquisition have not been included at this time.

**Table 2. Capital Cost Contingencies and Allowances**

| Item                                   | Markup | Comments                                                                                              |
|----------------------------------------|--------|-------------------------------------------------------------------------------------------------------|
| General Contractor Overhead and Profit | 15%    | Overhead and profit for general contractor                                                            |
| Contractor General Condition           | 12%    | Accounts for costs incurred at the jobsite for supervision and administration of the overall contract |
| Bonds and Insurance                    | 3.5%   | General contractor's performance bond and insurance fee                                               |
| Engineering                            | 20%    | Combined preliminary and final engineering services during design and bidding                         |
| Construction Engineering               | 15%    | Engineering services during construction                                                              |
| Legal and Administrative               | 5%     | Costs to LOTT for contract administration costs and legal review                                      |
| Undesigned Contingency                 | 35%    | Contingency to account for unforeseen changes that may be uncovered as design progresses              |

## 4.4 Capital Outlay Costs

For the purposes of developing capital cost for the two treatment trains, the following assumptions were made for each treatment train:

### 1. RO Treatment train

- A single pass RO system was assumed with an 87 percent recovery rate.
- For RO reject (i.e., brine) management, it is assumed that mechanical vapor compression is used for evaporation purposes, resulting in approximately 92 percent reduction in brine volume, which is then disposed of via landfill. Other approaches to brine management may be considered, such as 1) piping of brine to LOTT's Budd Inlet Treatment Plant where it would be blended with existing secondary effluent discharged into Budd Inlet, or 2) deep well injection. While these options may prove to have lower costs than mechanical evaporation, they are deemed infeasible as they both would represent continued introduction of residual chemicals into the environment (either Budd Inlet or the deep groundwater system), which runs counter to the primary objective of implementing advanced treatment.

- Advanced oxidation, in the form of ultraviolet light (UV) and hydrogen peroxide (H<sub>2</sub>O<sub>2</sub>), is coupled with RO to improve removal of certain chemicals, including NDMA.
- It was assumed that the RO feed pumps would be replaced every 10 years and the membrane elements would be replaced every 5 years over a 20-year lifecycle. These costs were included in the operation and maintenance (O&M) costs below.
- The overall footprint for a 1 mgd RO facility would be approximately 2,000 square feet, and that for a 5 mgd facility would be approximately 10,000 square feet.

## 2. Ozone-BAC-GAC Treatment train

- Ozone treatment system includes a liquid oxygen system, ozone generation system, cooling system, ozone mass transfer/dissolution systems, and ozone destruct system.
- GAC and BAC media made of bituminous coal were assumed. It was assumed that the media for both GAC and BAC would be replaced every 5 years over a 20-year lifecycle. These costs were included in the O&M costs below.
- The overall footprint for a 1 mgd facility would be approximately 6,000 square feet, and that for a 5 mgd facility would be approximately 30,000 square feet.

## 3. GAC Treatment train

- GAC media made of bituminous coal was assumed. It was assumed that the media for GAC would be replaced every 5 years over a 20-year lifecycle. These costs were included in the O&M costs below.
- The overall footprint for a 1 mgd facility would be approximately 3,000 square feet, and that for a 5 mgd facility would be approximately 15,000 square feet.

The OPPCs for the options are summarized in Table 3. These include base construction costs (i.e., materials, equipment, installation labor) as well as indirect costs and contingencies (i.e., the items listed in Table 2). The detailed cost spreadsheets, found in Appendix B, contain additional information and assumptions behind the cost estimates.

**Table 3. Capital Costs for Advanced Treatment Options**

| Treatment Option                | Capital Cost (\$ million) |
|---------------------------------|---------------------------|
| RO Treatment – 1 MGD            | \$33.6                    |
| RO Treatment – 5 MGD            | \$108.4                   |
| Ozone-BAC-GAC Treatment – 1 MGD | \$16.6                    |
| Ozone-BAC-GAC Treatment – 5 MGD | \$43.5                    |
| GAC Treatment – 1 MGD           | \$4.9                     |
| GAC Treatment – 5 MGD           | \$16.7                    |

## 4.5 Operation and Maintenance Costs

Annual O&M Costs were also developed for the options for a 20-year lifecycle, based on recent equipment costs and similar project experience. The O&M costs include operation of the proposed treatment systems on an ongoing basis. The key O&M cost assumptions are presented in Table 4, and the O&M costs are presented in Table 5.

**Table 4. O&M Cost Assumptions**

| Item  | Cost   | Unit     |
|-------|--------|----------|
| Power | \$0.09 | \$/kw-hr |
| Labor | \$52   | \$/hr    |

**Table 5. O&M Costs (Annual) for Advanced Treatment Options**

| Treatment Option                | O&M Cost    |
|---------------------------------|-------------|
| RO Treatment – 1 mgd            | \$3,400,000 |
| RO Treatment – 5 mgd            | \$8,800,000 |
| Ozone-BAC-GAC Treatment – 1 mgd | \$145,000   |
| Ozone-BAC-GAC Treatment – 5 mgd | \$380,000   |
| GAC Treatment – 1 mgd           | \$75,000    |
| GAC Treatment – 5 mgd           | \$200,000   |

## 4.6 20-Year Lifecycle Costs

The present value cost (i.e., in January 2022 dollars), combining capital and O&M costs, was determined for each of these treatment options over a 20-year lifecycle. These are presented below in Table 6.

**Table 6. Present Value (20-Year) Costs for Advanced Treatment Options**

| Treatment Option                | Present Value (\$million) |
|---------------------------------|---------------------------|
| RO Treatment – 1 mgd            | \$76.0                    |
| RO Treatment – 5 mgd            | \$218.7                   |
| Ozone-BAC-GAC Treatment – 1 mgd | \$18.5                    |
| Ozone-BAC-GAC Treatment – 5 mgd | \$48.3                    |
| GAC Treatment – 1 mgd           | \$5.8                     |
| GAC Treatment – 5 mgd           | \$19.2                    |

These present value costs do not take into account other factors that LOTT often uses in its cost/benefit or triple-bottom-line analyses, such as the monetized carbon footprint associated with the energy consumption and material hauling related to the various options. Such items may be considered in further evaluations.

## 5.0 Cost/Benefit Comparison Amongst Options

This section first presents a summary comparison of costs and benefits amongst the additional treatment options as they relate specifically to removal efficiencies of the two chemicals identified in the HHRA as exceeding the minimum level of concern. This is followed by a brief discussion of items to be further considered by LOTT either in the context of the RWIS or as part of its long-range master planning efforts exploring a wider range of management strategies.

### 5.1 Costs and Benefits of Various Treatment Approaches – Groundwater Recharge Focus

In this analysis, the benefit of applying additional levels of treatment to LOTT's reclaimed water can be evaluated as the associated reduction in level of risk. Table 7 presents a summary of this information, focused on the use of reclaimed water for groundwater recharge, combining the cost estimates discussed above with the results of the Task 3 risk assessment work. The No Advanced Treatment option reflects continued generation and use of Class A reclaimed water via LOTT's current treatment systems.

**Table 7. Cost and Groundwater Recharge Risk Reduction Benefit for Treatment Options**

| Treatment Option        | Cost <sup>a</sup><br>(20-yr PV,<br>\$million) |         | Cost per MG <sup>b</sup> |         | Highest Risk Level <sup>c</sup> |                                                                                                          |
|-------------------------|-----------------------------------------------|---------|--------------------------|---------|---------------------------------|----------------------------------------------------------------------------------------------------------|
|                         | 1 mgd                                         | 5 mgd   | 1 mgd                    | 5 mgd   | PFPeA                           | NDMA                                                                                                     |
| 1.No Advanced Treatment | ---                                           | ---     | ---                      | ---     | 1.3                             | $2.9 \times 10^{-6}$                                                                                     |
| 2.GAC                   | \$5.8                                         | \$19.2  | \$800                    | \$525   | 0.065                           | $2.9 \times 10^{-6}$<br>(Max; NDMA removal)<br>$2.8 \times 10^{-7}$<br>(Min.; NDMA precursor<br>removal) |
| 3.Ozone-BAC-GAC         | \$18.5                                        | \$48.3  | \$2,530                  | \$1,320 | 0.065 (Max.)<br>0.013 (Min.)    | $8.4 \times 10^{-7}$ (Max.)<br>$1.4 \times 10^{-7}$ (Min.)                                               |
| 4.RO-Based              | \$76.0                                        | \$218.7 | \$10,400                 | \$6,000 | 0.0                             | $1.1 \times 10^{-6}$ (Max.)<br>$5.8 \times 10^{-8}$ (Min.)                                               |

Notes:

a. See Table 6.

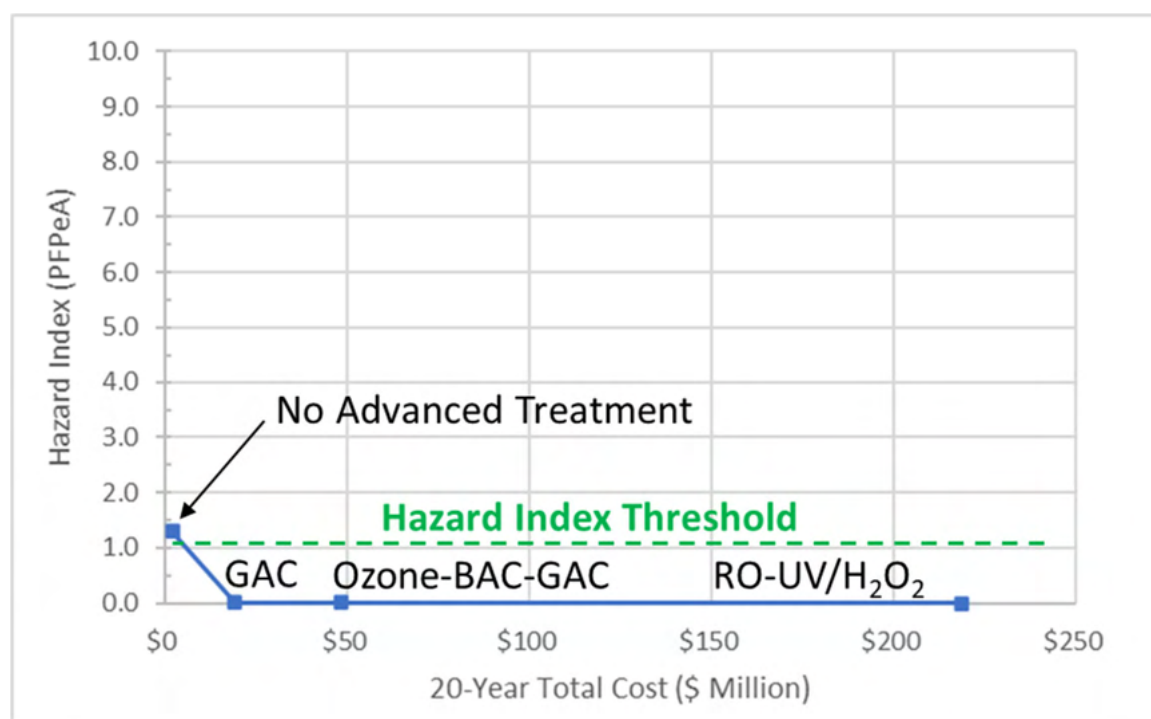
b. Based on 20 years of operation at stated treatment capacity (1 or 5 mgd).

c. As presented in the HHRA, based on the RME child resident scenario. Depicted as a range (maximum and minimum risk) in cases where reviewed treatment efficacy is characterized by a range (per Table 1). Specific notes:

- PFPeA. Non-cancer risk level presented as a Hazard Index (HI). Minimum threshold of concern is HI = 1.
- NDMA. Cancer risk level presented as Lifetime Excess Cancer Risk (LECR). *De minimis* cancer benchmark is  $1 \times 10^{-6}$ .

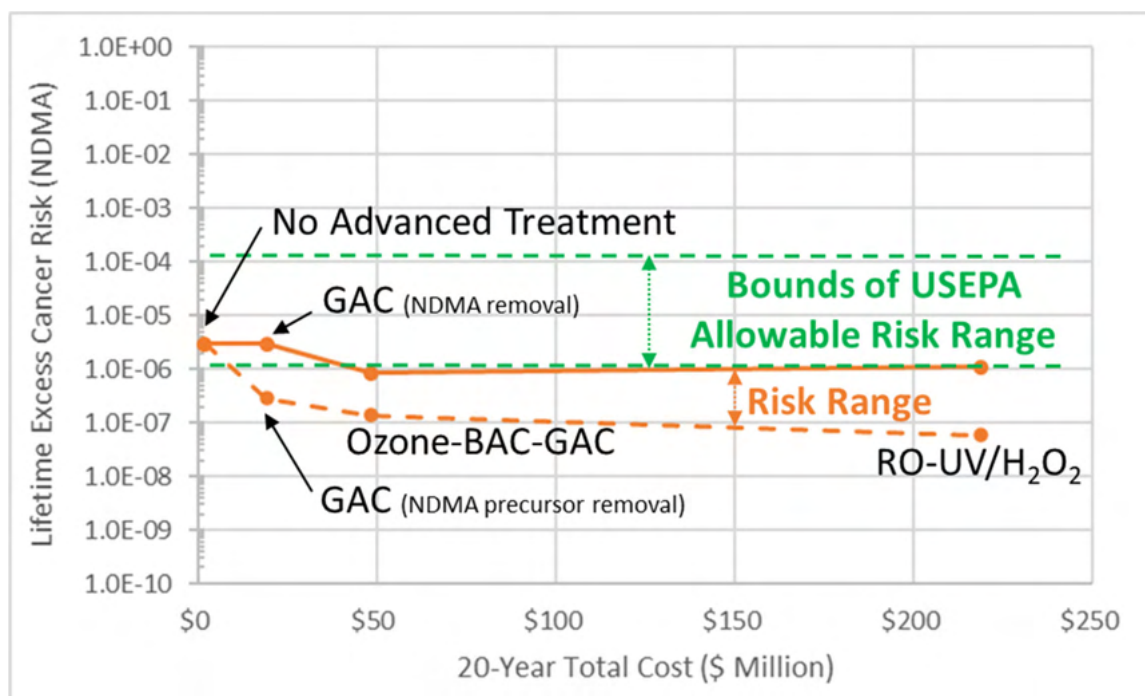
This information is also summarized on Figure 1 (for PFPeA)<sup>3</sup> and Figure 2 (for NDMA), where the 20-year present value costs for the 5 mgd treatment facility size are plotted against the HHRA results for each treatment option.

The No Advanced Treatment option may be considered a viable option, given the low level of risk identified in the risk assessments. All options of providing advanced levels of treatment reduce the highest risk levels to at or below minimum thresholds of concern. While the RO-based treatment train has the potential to result in the greatest risk reduction, it also carries the greatest cost. The GAC and Ozone-BAC-GAC options provide essentially the same risk reduction levels for PFPeA, with the GAC-only option having considerably less cost. The impact of the GAC-only option upon NDMA-related risk is a function of whether NDMA in LOTT's reclaimed water comes from NDMA that is present in influent wastewater or if it is formed during the disinfection stage of treatment. If it is predominantly the latter, GAC treatment can be effective at removing NDMA precursors, thereby preventing NDMA formation in reclaimed water. In this case, the NDMA-related risk is reduced similar to the Ozone-BAC-GAC treatment option. If NDMA is already present in influent wastewater, no removal by GAC is assumed and the risk level is considered unchanged from the No Advanced Treatment option. Therefore, further characterization of NDMA throughout LOTT's treatment processes is warranted if the GAC-only option is pursued.



**Figure 1. PFPeA Cost/Risk Comparison**

<sup>3</sup> No risk ranges are shown in Figure 1. As depicted in Table 7, a risk range is only shown for the Ozone-BAC-GAC option in relation to PFPeA removal. The range shown in Table 7 is too small to be clearly depicted at the scale presented in Figure 1.



**Figure 2. NDMA Cost/Risk Comparison**

## 5.2 Additional Factors to Consider Regarding Broader Cost Benefit Analysis

The above quantitative analysis is solely focused on evaluating the costs and benefits of various treatment levels applied to reclaimed water that is used for the purpose of groundwater recharge. This focus does not consider all aspects of costs and benefits. For example, treating water to a near-potable quality through an advanced treatment train could allow for alternative uses of the resource that may have additional associated benefits.

In addition, there are other approaches LOTT can take to address the risks that have been identified through the Task 3 risk assessment work. Given the low level of risk identified in the risk assessments, and the uncertainties inherent in the analysis, additional data gathering and/or other actions should be considered prior to or in place of modifying the level of treatment. These generally are approaches to be considered in conjunction with the No Advanced Treatment option (i.e., Option 1 in Table 7). The following strategies and actions do not represent a comprehensive list and have not been examined in detail at this point. These concepts will be considered further in the context of the RWIS and in LOTT's broader long-range master planning efforts. Such approaches include:

- Increased monitoring of residual chemicals of greatest interest, including NDMA and PFPeA (and other PFAS), to discern trends in concentrations, better understand the potential risk, and inform future management actions in response to changing conditions and regulations. This would include monitoring for NDMA and NDMA precursors at various stages within

LOTT's reclaimed water treatment processes, with a focus on better understanding presence of the chemical before and after current disinfection processes.

- Increased public outreach and education, aimed at: 1) enhancing the public's awareness of the costs and benefits of various water management approaches; 2) increasing the public's understanding of risk levels and risk management; and 3) reducing inputs of residual chemicals into the wastewater system.
- Sampling efforts to compare sources of residual chemicals and inform potential source control efforts. Consider comparison of residual chemicals in residential wastewater effluent, commercial/industrial effluent, landfill leachate, septic effluent, groundwater and surface water in areas influenced by reclaimed water and areas not influenced by reclaimed water.
- Targeted pretreatment of specific sources that contribute a higher proportion of residual chemicals to the wastewater system. At this time, no such sources are known, but if further analysis identifies them, localized advanced treatment of such waste streams could be more cost-effective than applying advanced treatment to the full quantity of reclaimed water produced at a LOTT facility.
- Support of broader industry efforts to regulate the sources of residual chemicals to reduce their inputs into the wastewater system.
- Modifying plans for future groundwater recharge. For example, LOTT could reduce or cease the use of reclaimed water for groundwater recharge purposes. Other uses, such as irrigation, could then be increased. However, it must be recognized that it is highly unlikely for others uses of reclaimed water to fully utilize the volume of water currently being utilized for groundwater recharge, especially during winter months. The impacts of redirecting this water to other points of final disposition (i.e., to marine water discharge) will need to be fully considered, including relation to evolving Puget Sound water quality management objectives and associated treated wastewater discharge constraints. These complex issues are being more comprehensively addressed in LOTT's master planning effort; thus, consideration of options like this may be best suited therein.

# **Appendix A      Memorandum: Proposed Additional Treatment Trains for Analysis**

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# Memorandum

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**To:** Wendy Steffensen, LOTT  
**From:** Jeff Hansen, HDR  
**Date:** September 14, 2021 (Revised May 11, 2022)  
**Subject:** Reclaimed Water Infiltration Study; Task 4 Cost/Benefit Analysis  
Proposed Additional Treatment Trains for Analysis

## 1.0 Introduction

Task 4 of the LOTT Clean Water Alliance (LOTT) Reclaimed Water Infiltration Study (RWIS) involves developing implementation costs for various reclaimed water treatment approaches and uses, which will then be used to prepare a cost/benefit analysis of options that weigh such treatment/use costs against their associated benefits in terms of human health and ecological risk reduction. LOTT currently produces Class A reclaimed water at both its Budd Inlet Reclaimed Water Plant (BIRWP) and Martin Way Reclaimed Water Plant (MWRWP). One of the objectives of Task 4 is to consider additional treatment trains that, if added to the current Class A treatment processes, would increase the removal efficiencies of residual chemicals that passed through the human health and ecological screening level risk evaluations and have been evaluated in more detail in the subsequent risk assessments (i.e., the work conducted in Task 3 of the RWIS).

This memorandum evaluates multiple potential treatment trains and recommends those for further consideration in the cost/benefit analysis. Once reviewed and refined by LOTT and the RWIS Science Task Force, in the broader context of meeting key objectives related to the cost/benefit analysis and the envisioned subsequent public outreach efforts, the selected treatment options will advance to planning-level cost estimating and incorporation into the cost/benefit analysis.

## 2.0 Residual Chemicals of Interest

Out of the residual chemicals that were detected in reclaimed water in at least one sampling event during execution of Tasks 1 and 2 of the RWIS, below is the subset of chemicals that have been focused upon in the Task 3 (risk assessment) work as LOTT's current level of treatment does not fully or consistently remove these chemicals from reclaimed water and they are of potential concern from a human health / ecological risk perspective:

- **1,4-Dioxane.** 1,4-dioxane is an industrial chemical with widespread use as a stabilizer in certain chlorinated solvents, paint strippers, greases and waxes. It has been identified as a likely human carcinogen by the U.S. Environmental Protection Agency (EPA) and has been found in groundwater at sites throughout the United States. The physical and chemical properties and behavior of 1,4-dioxane create challenges for its characterization and treatment. It is highly mobile and does not typically readily biodegrade in the environment.
- **4-Nonylphenol.** Nonylphenol is used in manufacturing antioxidants, lubricating oil additives, laundry and dish detergents, emulsifiers, and solubilizers. It is persistent in surface water due to its lipophilic properties and is known to be toxic to aquatic organisms above certain

threshold concentrations. It has also been shown to exhibit estrogenic properties in in vitro and in vivo assays.

- **Carbamazepine.** Carbamazepine is a pharmaceutical drug used to treat certain types of seizures such as epilepsy and is typically classified as an anticonvulsant. It has been considered a chemical of emerging concern due to its persistence in conventional treatment plants and widespread presence in water bodies. This is due to its low biodegradability and its tendency to remain associated with the aqueous phase. It has been shown to cause an increase in carcinomas in female rats.
- **Fipronil.** Fipronil is an insecticide used at high rates in urban environments. It usually remains stable in water at low or neutral pH but degrades in basic solutions. This compound and its biologically active degradation products have been detected in some urban runoff drainage and downstream surface water bodies at concentrations exceeding toxicity thresholds.
- **N-Nitrosodimethylamine (NDMA).** NDMA is a semivolatile organic chemical that was formerly used in the production of rocket fuel, antioxidants and softeners for copolymers, and is currently used mostly for research purposes, but is also found as a byproduct of water chlorination processes undertaken at water treatment facilities for disinfection. It is considered a drinking water contaminant of concern because of its carcinogenicity and toxicity. Due to its low molecular weight and hydrophilic nature, it is not easy to remove NDMA from water.
- **Primidone.** Primidone is a highly persistent pharmacological drug typically classified as an anticonvulsant. It is found in urban wastewaters and is considered a highly recalcitrant compound in water due to its uncharged nature. It has been identified by EPA as a probable human carcinogen.
- **Quinoline.** Quinoline is an industrial chemical used mainly as an intermediate in the manufacture of other products, and also as a catalyst, corrosion inhibitor, in metallurgical processes, in dye manufacture, as a preservative for anatomical specimens, in polymers and agricultural chemicals, and as a solvent for resins and terpenes. Due to the steric hindrance of its bicyclic structure and its long photooxidation half-life, quinoline does not readily decompose naturally in water. Quinoline is classified as “likely to be carcinogenic to humans” by EPA.
- **Per- and polyfluoroalkyl substances (PFAS).** PFAS are found in a wide range of consumer products that people use daily such as cookware and stain repellants. The two most studied groups of PFAS are two long-chain, sub-classes of PFAS: perfluoroalkyl carboxylic acids (PFCA) and perfluoroalkyl sulfonic acids (PFSA). Certain PFAS can accumulate and stay in the human body for long periods of time. There is evidence that exposure to PFAS can lead to adverse health outcomes in humans. Due to fluorine's electronegativity and the chemical stability of fluorinated compounds, PFAS molecules are challenging to remove from water. EPA has classified perfluorooctanoic acid (a subgroup of PFAS) as possibly carcinogenic to humans based on limited evidence for carcinogenicity in animals and in humans. PFAS has also high persistence and bioaccumulation potential in fish tissue and wildlife.

## 3.0 Proposed Treatment Trains

The Task 4 scope of work envisioned considering a reverse osmosis (RO) based treatment train and a non-RO option. This section explores the efficiencies of four different treatment trains (one being RO-based, and the other three being non-RO) to remove the residual chemicals highlighted in the prior section. The treatment trains considered are:

1. RO and Advanced Oxidation Processes (AOP). RO has historically been considered the “gold standard” when it comes to reclaimed water treatment, by physically separating contaminants from water. Adding an AOP unit process, like the ones described below, provides a multiple-barrier treatment approach for many contaminants and usually improves the overall performance.
2. Non-RO treatment. Although RO-AOP usually successfully removes most contaminants from reclaimed water, this approach can be extremely expensive and the associated post-treatment brine management can be challenging, particularly in areas where marine discharge of brine is not plausible (as is the case with LOTT). Therefore, non-RO treatment trains are increasingly being implemented throughout the reclaimed water industry and were explored here to compare their effectiveness against the RO-based treatment option. Such non-RO treatment approaches include unit processes such as:
  - Advanced Oxidation Process. AOPs are treatment processes that generate intermediate hydroxyl radicals that oxidize and remove organic contaminants in water. Ozone, hydrogen peroxide ( $H_2O_2$ ), and ultraviolet light (UV) are often used either alone or in various combinations as AOPs.
  - Enhanced biodegradation. The rate of biodegradation of organic contaminants in groundwater by microbes can be enhanced by increasing the concentration of electron acceptors such as oxygen, under aerobic conditions. Oxygen enhancement can be done by air sparging or by circulating a dilute solution through the groundwater to increase the oxygen content in the groundwater.
  - Filtration. The most commonly used filtration technologies other than RO are physical adsorption onto granular activated carbon (GAC) and biologically activated carbon (BAC) filtration. While GAC operates by adsorption of contaminants onto the carbon media surface, BAC filtration uses activated carbon as a carrier for microorganisms, which in turn biologically degrade contaminants present in water.

Literature research emphasized that instead of using a single non-RO treatment option, a combination of treatment options would provide a multiple-barrier system that would prove to be much more effective in removing most, if not all, residual chemicals. To this end, several treatment trains such as UV/ $H_2O_2$ -GAC, UV/ $H_2O_2$ -BAC, Ozone-GAC, and Ozone-BAC were reviewed. Considering the residual chemicals of interest, Ozone-BAC and Ozone-GAC were shortlisted due to their higher removal percentages as compared to other treatment trains. Many of the residual chemicals showed better removal rates with ozonation followed by BAC as opposed to GAC. However, compounds such as PFAS are best through GAC alone and pretreating with ozone can make the treatment inefficient. This is because ozone, by breaking down complex molecules, renders them biodegradable and effectively converts the GAC filter into a BAC filter. Once that occurs, the primary removal method becomes biodegradation rather than adsorption. Since PFAS is a significant chemical of interest in the

risk assessment, this led to the formation of the combined treatment train of Ozone-BAC-GAC which would provide the adsorption ability needed for PFAS removal with the final GAC filter. Therefore, the following non-RO treatment trains were evaluated:

- Ozone-GAC
- Ozone-BAC
- Ozone-BAC-GAC

Further simplification of the non-RO treatment train is possible if the primary focus is to remove PFPeA (and other PFAS), and NDMA to the extent possible. In this case, the non-RO treatment train is simplified to be GAC treatment alone. GAC is highly effective in removing PFAS, and although it only sparingly adsorbs NDMA, it has been shown to effectively reduce the formation potential of NDMA by greater than 90 percent by removing NDMA precursors. It is currently unknown to what extent NDMA is present in influent wastewater to LOTT's treatment facilities, versus how much NDMA may be formed as a result of the disinfection process. Therefore, more characterization is required to determine the effectiveness of GAC treatment on NDMA in LOTT's reclaimed water. Because of the biological nutrient removal (BNR) processes employed at LOTT's facilities, ammonia concentrations are low (typically well below 1 mg/L). NDMA formation is usually minimal under such conditions; hence, the majority of NDMA detected in LOTT's reclaimed water is probably present in influent wastewater as opposed to being generated during treatment. However, an evaluation involving sampling for NDMA before and after disinfection will help determine this. Bottom-line, GAC will likely only prove beneficial for NDMA removal if a high proportion of observed NDMA is formed during the disinfection process.

Table 1 presents the removal efficiencies for the focus residual chemicals through LOTT's existing Class A reclaimed water treatment processes and estimated percent removals associated with the above-mentioned treatment trains, based upon a literature review.

**Table 1. Removal efficiencies for potential treatment trains**

| Residual Chemical | Existing Class A Reclaimed Water Treatment % Removal (BIRWP / MWRWP)* | RO/RO-AOP % Removal (Treatment Train 1)                            | Ozone-GAC % Removal (Treatment Train 2) | Ozone-BAC % Removal (Treatment Train 3) | Ozone-BAC-GAC % Removal (Treatment Train 4) | GAC only % Removal (Treatment Train 5) |
|-------------------|-----------------------------------------------------------------------|--------------------------------------------------------------------|-----------------------------------------|-----------------------------------------|---------------------------------------------|----------------------------------------|
| 1,4-Dioxane       | NC / NC                                                               | 75-83 <sup>1</sup><br>(RO-UV/ H <sub>2</sub> O <sub>2</sub> )      | 40 <sup>2</sup>                         | 73 <sup>3</sup>                         | 50-73 <sup>4</sup>                          | 18-30 <sup>26</sup>                    |
| 4-Nonylphenol     | 72 / 77                                                               | 85-95 <sup>5</sup><br>(only RO)                                    | 92-98 <sup>6</sup>                      | >99 <sup>7</sup>                        | 99 <sup>4</sup>                             | >85 <sup>6</sup>                       |
| Carbamazepine     | 32 / 34                                                               | >95 <sup>8</sup><br>(only RO)                                      | 97.5 <sup>9</sup>                       | >93 <sup>10</sup>                       | 97.5 <sup>4</sup>                           | 24-62 <sup>27</sup>                    |
| Fipronil          | NC / NC                                                               | >95 <sup>11</sup><br>(only RO)                                     | 74-100 <sup>12</sup>                    | 74-100 <sup>12</sup>                    | 74-100 <sup>4</sup>                         | 40 <sup>28</sup>                       |
| NDMA              | 12 / 57                                                               | 62-98 <sup>13, 25</sup><br>(RO-UV/ H <sub>2</sub> O <sub>2</sub> ) | 32-78 <sup>14</sup>                     | >90 <sup>15</sup>                       | 70-94.4 <sup>16</sup>                       | 60-90 <sup>29</sup>                    |
| Primidone         | 38 / NC                                                               | >98 <sup>17</sup><br>(only RO)                                     | 61-87 <sup>18</sup>                     | 96 <sup>19</sup>                        | 96 <sup>4</sup>                             | 51 <sup>30</sup>                       |
| Quinoline         | 88 / 85                                                               | >90 <sup>20</sup><br>(only RO)                                     | 85 <sup>21</sup>                        | 85 <sup>21</sup>                        | 85-95 <sup>4</sup>                          | 93-98 <sup>31</sup>                    |
| PFAS              | 62 / NC **                                                            | >99 <sup>22</sup><br>(only RO)                                     | Inefficient <sup>23</sup>               | Inefficient <sup>23</sup>               | 95-99 <sup>24</sup>                         | >95 <sup>22</sup>                      |

\* Percentage (%) removal indicates the average removal calculated from all RWIS Task 1 sampling events (from November 2014 to August 2015) at the BIRWP and MWRWP. "NC" indicates Not Calculated (due to the chemical not being detected in raw wastewater, or detected in raw wastewater at a value lower than that in reclaimed water, therefore resulting in a negative % removal efficiency).

\*\* The only calculated PFAS removal value is for perfluoropentanoic acid. The data from one sampling event at the BIRWP yielded this result. In the case of all other PFAS chemicals analyzed, the result was "NC", per the above footnote.

Referenced data sources:

1. <https://www.waterrf.org/system/files/resource/2021-06/EXECSUM-4991.pdf>.
2. Vatankhah, H., Szczuka, A., Mitch, W. A., Almaraz, N., Brannum, J., & Bellona, C. (2019). Evaluation of enhanced ozone–biologically active filtration treatment for the removal of 1, 4-dioxane and disinfection byproduct precursors from wastewater effluent. *Environmental science & technology*, 53(5), 2720-2730.
3. <https://www.reno.gov/home/showdocument?id=30769>.
4. Highest removal percentage taken from the Ozone-GAC and Ozone-BAC treatment trains.
5. Liu, Z. H., Kanjo, Y., & Mizutani, S. (2009). Removal mechanisms for endocrine disrupting compounds (EDCs) in wastewater treatment—physical means, biodegradation, and chemical advanced oxidation: a review. *Science of the total environment*, 407(2), 731-748.
6. Choi, K. J., Kim, S. G., Kim, C. W., & Park, J. K. (2006). Removal efficiencies of endocrine disrupting chemicals by coagulation/flocculation, ozonation, powdered/granular activated carbon adsorption, and chlorination. *Korean Journal of Chemical Engineering*, 23(3), 399-408.
7. Chys, M., Demeestere, K., Ingabire, A. S., Dries, J., Van Langenhove, H., & Van Hulle, S. W. (2017). Enhanced treatment of secondary municipal wastewater effluent: comparing (biological) filtration and ozonation in view of micropollutant removal, unselective effluent toxicity, and the potential for real-time control. *Water Science and Technology*, 76(1), 236-246.
8. Hai, F. I., Yang, S., Asif, M. B., Sencadas, V., Shawkat, S., Sanderson-Smith, M., ... & Yamamoto, K. (2018). Carbamazepine as a possible anthropogenic marker in water: occurrences, toxicological effects, regulations and removal by wastewater treatment technologies. *Water*, 10(2), 107.
9. Ternes, T. A., Meisenheimer, M., McDowell, D., Sacher, F., Brauch, H. J., Haist-Gulde, B., ... & Zulei-Seibert, N. (2002). Removal of pharmaceuticals during drinking water treatment. *Environmental science & technology*, 36(17), 3855-3863.
10. Trussell, R. S., A. N. Pisarenko, and E. Chen. "Implementation of advanced water purification facility extended testing." City of San Diego, CA. Retrieved from: Public Utilities Department. [https://www.sandiego.gov/sites/default/files/implementation\\_of\\_awp\\_facility\\_extended\\_testing\\_project\\_report\\_july\\_2015.pdf](https://www.sandiego.gov/sites/default/files/implementation_of_awp_facility_extended_testing_project_report_july_2015.pdf) (2015).
11. Based on the molecular size and conversation with Pierre Kwan, PE, Water Treatment Business Class Technical Director at HDR.
12. Zhang, Z., King, J. F., Szczuka, A., Chuang, Y. H., & Mitch, W. A. (2020). Pilot-scale ozone/biological activated carbon treatment of reverse osmosis concentrate: potential for synergism between nitrate and contaminant removal and potable reuse. *Environmental Science: Water Research & Technology*, 6(5), 1421-1431.
13. Plumlee, M. H., López-Mesas, M., Heidberger, A., Ishida, K. P., & Reinhard, M. (2008). N-nitrosodimethylamine (NDMA) removal by reverse osmosis and UV treatment and analysis via LC–MS/MS. *Water research*, 42(1-2), 347-355.
14. Verdugo, E. M., Gifford, M., Glover, C., Cuthbertson, A. A., Trenholm, R. A., Kimura, S. Y., ... & Dickenson, E. R. (2020). Controlling disinfection byproducts from treated wastewater using adsorption with granular activated carbon: Impact of pre-ozonation and pre-chlorination. *Water research X*, 9, 100068.
15. Bacaro, F., Dickenson, E., Trenholm, R. A., & Gerrity, D. (2019). N-Nitrosodimethylamine (NDMA) formation and mitigation in potable reuse treatment trains employing ozone and biofiltration. *Environmental Science: Water Research & Technology*, 5(4), 713-725.
16. Hogard, S., Salazar-Benites, G., Pearce, R., Nading, T., Schimmoller, L., Wilson, C., ... & Bott, C. Demonstration-scale evaluation of ozone–biofiltration–granular activated carbon advanced water treatment for managed aquifer recharge. *Water Environment Research*.

17. Konradt, N., Kuhlen, J. G., Rohns, H. P., Schmitt, B., Fischer, U., Binder, T., ... & Panglisch, S. (2021). Removal of Trace Organic Contaminants by Parallel Operation of Reverse Osmosis and Granular Activated Carbon for Drinking Water Treatment. *Membranes*, 11(1), 33.
18. Vatankhah, H., Riley, S. M., Murray, C., Quiñones, O., Steirer, K. X., Dickenson, E. R., & Bellona, C. (2019). Simultaneous ozone and granular activated carbon for advanced treatment of micropollutants in municipal wastewater effluent. *Chemosphere*, 234, 845-854.
19. Sundaram, V., & Pagilla, K. (2020). Trace and bulk organics removal during ozone–biofiltration treatment for potable reuse applications. *Water Environment Research*, 92(3), 430-440.
20. Albergamo, V., Blankert, B., Cornelissen, E. R., Hofs, B., Knibbe, W. J., van der Meer, W., & de Voogt, P. (2019). Removal of polar organic micropollutants by pilot-scale reverse osmosis drinking water treatment. *Water research*, 148, 535-545.
21. Wang, L., Gao, Q., Li, Z., & Wang, Y. (2020). Improved Removal of Quinoline from Wastewater Using Coke Powder with Inorganic Ions. *Processes*, 8(2), 156.
22. American Water Works Association. (2020). Drinking Water Treatment for PFAS Selection Guide. <https://www.awwa.org/Portals/0/AWWA/ETS/Resources/Technical%20Reports/Drinking-Water-Treatment-PFAS.pdf?ver=2020-11-10-100726-250>.
23. Conversation with Pierre Kwan, PE, Water Treatment Business Class Technical Director at HDR.
24. Conversation with Christina Alito, PhD, PE, Mid-Atlantic Drinking Water Lead at HDR.
25. Tackaert, Rodrigo A., et al. (2019). Demonstrating process robustness of potable reuse trains during challenge testing with elevated levels of acetone, formaldehyde, NDMA, and 1, 4-dioxane. *Journal of Water Supply: Research and Technology-AQUA* 68.5: 313-324.
26. Fotta, M. E. (2012). Effect of Granular Activated Carbon Type on Adsorber Performance and Scale-Up Approaches for Volatile Organic Compound Removal.
27. Rizzo, L., Fiorentino, A., Grassi, M., Attanasio, D., & Guida, M. (2015). Advanced treatment of urban wastewater by sand filtration and graphene adsorption for wastewater reuse: Effect on a mixture of pharmaceuticals and toxicity. *Journal of environmental chemical engineering*, 3(1), 122-128.
28. Dang, V. D., Kroll, K. J., Supowit, S. D., Halden, R. U., & Denslow, N. D. (2018). Activated carbon as a means of limiting bioaccumulation of organochlorine pesticides, triclosan, triclocarban, and fipronil from sediments rich in organic matter. *Chemosphere*, 197, 627-633.
29. Hanigan, D., Zhang, J., Herckes, P., Krasner, S. W., Chen, C., & Westerhoff, P. (2012). Adsorption of N-nitrosodimethylamine precursors by powdered and granular activated carbon. *Environmental Science & Technology*, 46(22), 12630-12639.
30. Yang, Y., Ricoveri, A., Demeestere, K., & Van Hulle, S. (2022). Surrogate-based follow-up of activated carbon adsorption preceded by ozonation for removal of bulk organics and micropollutants from landfill leachate. *Science of The Total Environment*, 153349.
31. Rameshraj, D., Srivastava, V. C., Kushwaha, J. P., & Mall, I. D. (2012). Quinoline adsorption onto granular activated carbon and bagasse fly ash. *Chemical Engineering Journal*, 181, 343-351.

Details regarding the efficacy of these treatment options for each chemical are provided below.

- **1,4-Dioxane.** Due to its small molecular size, RO does not reject 1,4-dioxane completely, but it fairs better than the Ozone-GAC treatment train. Ozone-BAC has shown to be fairly equally effective in removing the compound as RO.
- **4-Nonylphenol.** Literature research shows that Ozone-BAC treatment train provides the highest removal efficiency for 4-nonylphenol. The ozone pretreatment makes the compound more readily available for biofiltration using BAC which allows for a higher removal rate.
- **Carbamazepine.** Due to carbamazepine's high adsorption capacity, Ozone-GAC works best in removing the compound, although all treatment trains have comparable removal percentages.

- **Fipronil.** Considering that the compound has a large molecular size, RO should be effective in its elimination. Due to limited research available on the Ozone-GAC treatment for Fipronil, same percent removal range was applied for it as for the Ozone-BAC treatment train.
- **NDMA.** RO treatment alone provides only moderate rejection for NDMA because it is hydrophilic in nature and is uncharged. Advanced oxidation aids in increasing removal efficiency. Ozone-BAC proved to be efficient in its removal, as the NDMA generated upon ozonation is typically effectively biodegraded using BAC filters. Generally, an Empty Bed Contact Time (EBCT) of 10-20 minutes is shown to be sufficient in achieving high removal rates for NDMA. As described above, GAC alone is not effective at removing NDMA, but it can prevent formation of NDMA if placed prior to disinfection, so as to remove NDMA precursors.
- **Primidone.** While RO is successful in rejecting primidone, Ozone-BAC treatment is equally effective in its removal at a higher EBCT of 20 minutes and under low organic loading rates.
- **Quinoline.** Due to its large molecular size, this is removed by RO treatment fairly well. Research on quinoline removal through adsorption is limited and the percent removal from its adsorption on coke powder was applied to treatment trains 2, 3, and 4.
- **PFAS.** RO has been proven to remove both short-chain and long-chain PFAS and offers an extremely high removal percentage of more than 99%. Ozone-GAC and Ozone-BAC are inefficient in removing PFAS due to the reduced adsorptive capability of GAC filters post ozonation. However, Ozone-BAC-GAC is a comparable method to RO in terms of PFAS removal efficiencies. GAC alone can also be highly effective at removing PFAS.

## 4.0 Additional Focus on NDMA and PFAS

Upon completion of the draft risk assessment documents in mid-August 2021, additional consideration was given to options for targeted treatment of NDMA and PFAS. This is because for the exposure point concentrations being considered, NDMA was the only chemical for which a lifetime excess cancer risk was found to exceed the de minimis benchmark of 1 in 1,000,000, while perfluoropentanoic acid (PFPeA, one of the PFAS chemicals) was the only chemical whose estimated non-cancer hazard index exceeded the threshold of 1.0. As such, the cost-benefit analysis may include consideration of approaches to specifically manage these particular chemicals. From a treatment perspective, the following represent typical ways in which these chemicals are removed from reclaimed water:

- **NDMA.** As described in Section 3, NDMA can be present in wastewater due to both: a) sources in the sewer collection system that introduce it to the raw wastewater; and, b) formation during the disinfection part of the treatment process. Hence, its removal can be challenging. However, there are a couple targeted treatment approaches that could be used for its removal:
  - **Ozone-BAC.** Research has shown that the Ozone-BAC treatment train is quite effective in removing NDMA. The NDMA that is formed post ozonation can be efficiently removed by the BAC treatment.
  - **BAC-Ozone.** Often it makes sense to add some filtration to remove formation precursors (organic matter) before the oxidation process (e.g., via ozone). This way any NDMA in the raw wastewater is removed using BAC (or potentially GAC) and

any inadvertent formation of it through ozonation is minimized by removing the precursors that react with ozone to form NDMA. However, the BAC-Ozone sequence is specific to NDMA and might not be as effective as the reverse sequence in removal of other residual chemicals.

- UV photolysis. While UV photolysis is extremely effective in removing NDMA, it typically requires extremely high UV doses and therefore has a high energy/operational cost. The BAC-based options above can be much more cost effective.
- GAC. As discussed previously, GAC is not effective at adsorbing NDMA, but it has been shown to effectively reduce the formation potential of NDMA by greater than 90 percent by removing NDMA precursors.
- **PFPeA.** Removal of PFPeA only requires the GAC portion of the Ozone-BAC-GAC train. That is the simplest, most effective, and typical treatment currently being employed. Another alternative is using ion-exchange resins, though that option typically does not perform as well as GAC.

## 5.0 Summary

In conclusion, while RO treatment provides increased removal for the residual chemicals of interest, one of the major and costly challenges with RO membrane operation is the disposal of the concentrate stream created by the process. Ozone-BAC-GAC is a robust potential alternative to RO. Further examination of these two treatment trains would provide good contrast in the Task 4 cost/benefit analysis.

In addition, if the cost/benefit analysis is expanded to consider targeted treatment of only NDMA or PFAS, then the simplified trains of BAC-ozone or GAC alone should be considered, respectively. The most streamlined advanced treatment approach would be the use of GAC. This would prove effective at removing PFAS. It would not increase removal of NDMA, but it could prevent formation of NDMA during the disinfection stage of treatment. This would be beneficial only if it is demonstrated that formation during treatment is the predominant source of NDMA in LOTT's reclaimed water.

## **Appendix B      Advanced Treatment Cost Estimates**

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# RO-AOP (1 MGD)

| Reverse Osmosis - Large 1-200 mgd                        |                        |                   |                   |                   |                      |               |
|----------------------------------------------------------|------------------------|-------------------|-------------------|-------------------|----------------------|---------------|
| Process Size                                             |                        |                   |                   |                   |                      |               |
| Base Property                                            | Units                  | Min of Cost Range | Max of Cost Range | Design Cost Basis | Operating Cost Basis |               |
| flow                                                     | MGD                    | 0                 | 0                 | 1                 | 1                    |               |
| Construction Costs                                       |                        |                   |                   |                   |                      |               |
| Base Cost                                                | Equipment              | Labor             | Material          | Other             | Subcontract          | Subtotal      |
| Building                                                 |                        |                   |                   |                   |                      | \$ 501,000    |
| Labor                                                    |                        |                   |                   |                   |                      | \$ 207,000    |
| RO Equipment                                             |                        |                   |                   |                   |                      | \$ 650,000    |
| UV H2O2 System                                           |                        |                   |                   |                   |                      | \$ 480,000    |
| Mechanical Vapor Compression (Brine Mgmt)                |                        |                   |                   |                   |                      | \$ 2,500,000  |
| A. Subtotal                                              |                        |                   |                   |                   |                      | \$ 4,338,000  |
| Additions/Contingency                                    |                        |                   |                   |                   |                      |               |
| Items                                                    | Formula                |                   |                   |                   |                      | Cost          |
| B. Miscellaneous and Unidentified Site Structures        | (A*0.25)               |                   |                   |                   |                      | \$ 1,084,500  |
| C. Unit Process Subtotal                                 | (A+B)                  |                   |                   |                   |                      | \$ 5,422,500  |
| D. Sitework                                              | (C*0.15)               |                   |                   |                   |                      | \$ 813,375    |
| E. Demolition                                            | (C*0)                  |                   |                   |                   |                      | \$ -          |
| F. I&C (SCADA)                                           | (C*0.08)               |                   |                   |                   |                      | \$ 433,800    |
| G. Site Electrical                                       | (C*0.1)                |                   |                   |                   |                      | \$ 542,250    |
| H. Large Piping and Specialty piping                     | (C*0.05)               |                   |                   |                   |                      | \$ 271,125    |
| J. Soil Conditions (Geotechnical requirements)           | (C*0.07)               |                   |                   |                   |                      | \$ 379,575    |
| K. Field General Conditions                              | (C*0.07)               |                   |                   |                   |                      | \$ 379,575    |
| L. Mobilization and Demobilization                       | (C*0.05)               |                   |                   |                   |                      | \$ 271,125    |
| M. Construction Subtotal (excluding miscellaneous items) | (C+D+E+F+G+H+J+K+L)    |                   |                   |                   |                      | \$ 8,513,325  |
| N. Miscellaneous Elements not Itemized                   | (M*0.2)                |                   |                   |                   |                      | \$ 1,702,665  |
| P. Non-Construction Fees                                 | (P)                    |                   |                   |                   |                      | \$ -          |
| R. Construction Subtotal (including miscellaneous items) | (M+N+P)                |                   |                   |                   |                      | \$ 10,215,990 |
| S. Sales Tax                                             | (R*0.094)              |                   |                   |                   |                      | \$ 960,303    |
| T. General Contractor OH and Profit                      | ((R+S)*0.15)           |                   |                   |                   |                      | \$ 1,676,444  |
| U. Bonds and Insurance                                   | ((R+S+T)*0.035)        |                   |                   |                   |                      | \$ 449,846    |
| V. Construction Price Today                              | (R+S+T+U)              |                   |                   |                   |                      | \$ 13,302,583 |
| W. Projection to Mid-point of Construction               | (V*0)                  |                   |                   |                   |                      | \$ -          |
| X. Market adjustment factor                              | (V*0)                  |                   |                   |                   |                      | \$ -          |
| Y. Location adjustment factor                            | (V*0)                  |                   |                   |                   |                      | \$ -          |
| Z. Construction Bid Price                                | (V+W+X+Y)              |                   |                   |                   |                      | \$ 13,302,583 |
| AA. Undersigned Contingency                              | (Z*0.35)               |                   |                   |                   |                      | \$ 4,655,904  |
| AB. Construction Budget Price                            | (Z+AA)                 |                   |                   |                   |                      | \$ 17,958,487 |
| AC. Engineering Design Services                          | (AB*0.20)              |                   |                   |                   |                      | \$ 3,591,697  |
| AD. Engineering Services During Construction             | (AB*0.15)              |                   |                   |                   |                      | \$ 2,693,773  |
| AE. Construction Administration (CA)                     | (AB*0.04)              |                   |                   |                   |                      | \$ 718,339    |
| AF. Construction Inspection (CI)                         | (AB*0.07)              |                   |                   |                   |                      | \$ 1,257,094  |
| AG. Legal and Fiscal                                     | (AB*0.05)              |                   |                   |                   |                      | \$ 897,924    |
| AH. Owner Administration                                 | (AB*0.12)              |                   |                   |                   |                      | \$ 2,155,018  |
| CIP, Total Project Capital Cost                          | (AB+AC+AD+AE+AF+AG+AH) |                   |                   |                   |                      | \$ 29,272,333 |
| Operations/Maintenance                                   |                        |                   |                   |                   |                      |               |
| Operation                                                | Unit Rates             | Cost Units        | Annual Rates      | Annual Units      |                      |               |
| Building Energy                                          | 0.09 \$/kWh            |                   | 999 kWh/yr        |                   | \$                   | 90            |
| Diesel                                                   |                        |                   |                   |                   | \$                   | -             |
| Labor                                                    | 52 \$/hr               |                   | 1613 hr/yr        |                   | \$                   | 83,862        |
| Membrane replacement                                     | \$ 325,000 \$/unit     |                   | 3 \$/20 yrs       |                   | \$                   | 48,750        |
| RO feed pump replacement                                 | \$ 80,000 \$/unit      |                   | 2 \$/20 yrs       |                   | \$                   | 8,000         |
| Well Injection Pump replacement                          | \$ - \$/unit           |                   | 2 \$/20 yrs       |                   | \$                   | -             |
| Process Energy                                           | 0.09 \$/kWh            |                   | 2364801 kWh/yr    |                   | \$                   | 212,832       |
| UV disinfection                                          |                        |                   |                   |                   | \$                   | 37,000        |
| Brine Management                                         |                        |                   |                   |                   | \$                   | 3,000,000     |
| Subtotal (O&M)                                           |                        |                   |                   |                   | \$                   | 3,390,534     |
| Chemicals                                                |                        |                   |                   |                   |                      |               |
| Chemical Name                                            | Chemical Cost          | Cost Units        | Amount            | Consumption Units |                      | Cost          |
| Large Cylinder Chlorine                                  |                        | 1 ton             | 350 ton/yr        |                   | \$                   | 1,530         |
| Hexametaphosphate                                        |                        | 1 ton             | 1300 ton/yr       |                   | \$                   | 5,690         |
| Sulfuric Acid                                            |                        | 1 ton             | 100 ton/yr        |                   | \$                   | 438           |
| Subtotal (Chemical)                                      |                        |                   |                   |                   | \$                   | 7,658         |

# RO-AOP (5 MGD)

## Reverse Osmosis - Large 1-200 mgd

### Process Size

| Base Property | Units | Min of Cost Range | Max of Cost Range | Design Cost Basis | Operating Cost Basis |
|---------------|-------|-------------------|-------------------|-------------------|----------------------|
| flow          | MGD   | 0                 | 0                 | 5                 | 5                    |

### Construction Costs

| Base Cost                                 | Equipment | Labor | Material | Other | Subcontract | Subtotal      |
|-------------------------------------------|-----------|-------|----------|-------|-------------|---------------|
| Building                                  |           |       |          |       |             | \$ 1,760,000  |
| Labor                                     |           |       |          |       |             | \$ 664,000    |
| RO Equipment                              |           |       |          |       |             | \$ 3,500,000  |
| UV H2O2 System                            |           |       |          |       |             | \$ 570,000    |
| Mechanical Vapor Compression (Brine Mgmt) |           |       |          |       |             | \$ 7,500,000  |
| A. Subtotal                               |           |       |          |       |             | \$ 13,994,000 |

### Additions/Contingency

| Items                                                    | Formula                |  |  |  |  | Cost          |
|----------------------------------------------------------|------------------------|--|--|--|--|---------------|
| B. Miscellaneous and Unidentified Site Structures        | (A*0.25)               |  |  |  |  | \$ 3,498,500  |
| C. Unit Process Subtotal                                 | (A+B)                  |  |  |  |  | \$ 17,492,500 |
| D. Sitework                                              | (C*0.15)               |  |  |  |  | \$ 2,623,875  |
| E. Demolition                                            | (C*0)                  |  |  |  |  | \$ -          |
| F. I&C (SCADA)                                           | (C*0.08)               |  |  |  |  | \$ 1,399,400  |
| G. Site Electrical                                       | (C*0.1)                |  |  |  |  | \$ 1,749,250  |
| H. Large Piping and Specialty piping                     | (C*0.05)               |  |  |  |  | \$ 874,625    |
| J. Soil Conditions (Geotechnical requirements)           | (C*0.07)               |  |  |  |  | \$ 1,224,475  |
| K. Field General Conditions                              | (C*0.07)               |  |  |  |  | \$ 1,224,475  |
| L. Mobilization and Demobilization                       | (C*0.05)               |  |  |  |  | \$ 874,625    |
| M. Construction Subtotal (excluding miscellaneous items) | (C+D+E+F+G+H+J+K+L)    |  |  |  |  | \$ 27,463,225 |
| N. Miscellaneous Elements not Itemized                   | (M*0.2)                |  |  |  |  | \$ 5,492,645  |
| P. Non-Construction Fees                                 | (P)                    |  |  |  |  | \$ -          |
| R. Construction Subtotal (including miscellaneous items) | (M+N+P)                |  |  |  |  | \$ 32,955,870 |
| S. Sales Tax                                             | (R*0.094)              |  |  |  |  | \$ 3,097,852  |
| T. General Contractor OH and Profit                      | ((R+S)*0.15)           |  |  |  |  | \$ 5,408,058  |
| U. Bonds and Insurance                                   | ((R+S+T)*0.035)        |  |  |  |  | \$ 1,451,162  |
| V. Construction Price Today                              | (R+S+T+U)              |  |  |  |  | \$ 42,912,942 |
| W. Projection to Mid-point of Construction               | (V*0)                  |  |  |  |  | \$ -          |
| X. Market adjustment factor                              | (V*0)                  |  |  |  |  | \$ -          |
| Y. Location adjustment factor                            | (V*0)                  |  |  |  |  | \$ -          |
| Z. Construction Bid Price                                | (V+W+X+Y)              |  |  |  |  | \$ 42,912,942 |
| AA. Undersigned Contingency                              | (Z*0.35)               |  |  |  |  | \$ 15,019,530 |
| AB. Construction Budget Price                            | (Z+AA)                 |  |  |  |  | \$ 57,932,472 |
| AC. Engineering Design Services                          | (AB*0.20)              |  |  |  |  | \$ 11,586,494 |
| AD. Engineering Services During Construction             | (AB*0.15)              |  |  |  |  | \$ 8,689,871  |
| AE. Construction Administration (CA)                     | (AB*0.04)              |  |  |  |  | \$ 2,317,299  |
| AF. Construction Inspection (CI)                         | (AB*0.07)              |  |  |  |  | \$ 4,055,273  |
| AG. Legal and Fiscal                                     | (AB*0.05)              |  |  |  |  | \$ 2,896,624  |
| AH. Owner Administration                                 | (AB*0.12)              |  |  |  |  | \$ 6,951,897  |
| CIP. Total Project Capital Cost                          | (AB+AC+AD+AE+AF+AG+AH) |  |  |  |  | \$ 94,429,930 |

### Operations/Maintenance

| Operation                       | Unit Rates   | Cost Units | Annual Rates | Annual Units |              |
|---------------------------------|--------------|------------|--------------|--------------|--------------|
| Building Energy                 | 0.09         | \$/kWh     | 4508         | kWh/yr       | \$ 406       |
| Diesel                          |              |            |              |              | \$ -         |
| Labor                           | 52           | \$/hr      | 2764         | hr/yr        | \$ 143,733   |
| Membrane replacement            | \$ 1,750,000 | \$/unit    | 3            | \$/20 yrs    | \$ 262,500   |
| RO feed pump replacement        | \$ 150,000   | \$/unit    | 2            | \$/20 yrs    | \$ 15,000    |
| Well Injection Pump replacement | \$ -         | \$/unit    | 2            | \$/20 yrs    | \$ -         |
| Process Energy                  | 0.09         | \$/kWh     | 11536082     | kWh/yr       | \$ 1,038,247 |
| UV Disinfection                 |              |            |              |              | \$ 50,000    |
| Brine Mangement                 |              |            |              |              | \$ 7,300,000 |
| Subtotal (O&M)                  |              |            |              |              | \$ 8,809,886 |

### Chemicals

| Chemical Name           | Chemical Cost | Cost Units | Amount | Consumption Units | Cost      |
|-------------------------|---------------|------------|--------|-------------------|-----------|
| Large Cylinder Chlorine |               | 5 ton      | 350    | ton/yr            | \$ 7,660  |
| Hexametaphosphate       |               | 5 ton      | 1300   | ton/yr            | \$ 28,500 |
| Sulfuric Acid           |               | 5 ton      | 100    | ton/yr            | \$ 2,190  |
| Subtotal (Chemical)     |               |            |        |                   | \$ 38,350 |

# Ozone-BAC-GAC (1 MGD)

| GAC-BAC System                                           |                        |                   |                   |                   |                      |              |
|----------------------------------------------------------|------------------------|-------------------|-------------------|-------------------|----------------------|--------------|
| Process Size                                             |                        |                   |                   |                   |                      |              |
| Base Property                                            | Units                  | Min of Cost Range | Max of Cost Range | Design Cost Basis | Operating Cost Basis |              |
| contactor bed volume                                     | ft³                    | 0                 | 0                 | 7300              | 7300                 |              |
| Construction Costs                                       |                        |                   |                   |                   |                      |              |
| Base Cost                                                | Equipment              | Labor             | Material          | Other             | Subcontract          | Subtotal     |
| Building                                                 |                        |                   |                   |                   |                      | \$ 303,000   |
| Excavation & Sitework                                    |                        |                   |                   |                   |                      | \$ 1,890     |
| Labor                                                    |                        |                   |                   |                   |                      | \$ 51,500    |
| Equipment                                                |                        |                   |                   |                   |                      | \$ 222,000   |
| Media                                                    |                        |                   |                   |                   |                      | \$ 257,518   |
| Concrete                                                 |                        |                   |                   |                   |                      | \$ 7,220     |
| Steel                                                    |                        |                   |                   |                   |                      | \$ 4,180     |
| Pipe & Valves                                            |                        |                   |                   |                   |                      | \$ 72,600    |
| A. Subtotal                                              |                        |                   |                   |                   |                      | \$ 919,908   |
| Additions/Contingency                                    |                        |                   |                   |                   |                      |              |
| Items                                                    | Formula                |                   |                   |                   |                      | Cost         |
| B. Miscellaneous and Unidentified Site Structures        | (A*0.25)               |                   |                   |                   |                      | \$ 229,977   |
| C. Unit Process Subtotal                                 | (A+B)                  |                   |                   |                   |                      | \$ 1,149,885 |
| D. Sitework                                              | (C*0.15)               |                   |                   |                   |                      | \$ 172,483   |
| E. Demolition                                            | (C*0.01)               |                   |                   |                   |                      | \$ -         |
| F. I&C (SCADA)                                           | (C*0.08)               |                   |                   |                   |                      | \$ 91,991    |
| G. Site Electrical                                       | (C*10)                 |                   |                   |                   |                      | \$ 114,988   |
| H. Large Piping and Specialty piping                     | (C*0.05)               |                   |                   |                   |                      | \$ 57,494    |
| J. Soil Conditions (Geotechnical requirements)           | (C*0.07)               |                   |                   |                   |                      | \$ 80,492    |
| K. Field General Conditions                              | (C*0.07)               |                   |                   |                   |                      | \$ 80,492    |
| L. Mobilization and Demobilization                       | (C*0.05)               |                   |                   |                   |                      | \$ 57,494    |
| M. Construction Subtotal (excluding miscellaneous items) | (C+D+E+F+G+H+J+K+L)    |                   |                   |                   |                      | \$ 1,805,319 |
| N. Miscellaneous Elements not Itemized                   | (M*0.2)                |                   |                   |                   |                      | \$ 361,064   |
| P. Non-Construction Fees                                 | (P)                    |                   |                   |                   |                      | \$ -         |
| R. Construction Subtotal (including miscellaneous items) | (M+N+P)                |                   |                   |                   |                      | \$ 2,166,383 |
| S. Sales Tax                                             | (R*0.094)              |                   |                   |                   |                      | \$ 203,640   |
| T. General Contractor OH and Profit                      | ((R+S)*0.15)           |                   |                   |                   |                      | \$ 355,503   |
| U. Bonds and Insurance                                   | ((R+S+T)*0.035)        |                   |                   |                   |                      | \$ 95,393    |
| V. Construction Price Today                              | (R+S+T+U)              |                   |                   |                   |                      | \$ 2,820,919 |
| W. Projection to Mid-point of Construction               | (V*0)                  |                   |                   |                   |                      | \$ -         |
| X. Market adjustment factor                              | (V*0)                  |                   |                   |                   |                      | \$ -         |
| Y. Location adjustment factor                            | (V*0)                  |                   |                   |                   |                      | \$ -         |
| Z. Construction Bid Price                                | (V+W+X+Y)              |                   |                   |                   |                      | \$ 2,820,919 |
| AA. Undesigned Contingency                               | (Z*0.35)               |                   |                   |                   |                      | \$ 987,322   |
| AB. Construction Budget Price                            | (Z+AA)                 |                   |                   |                   |                      | \$ 3,808,241 |
| AC. Engineering Design Services                          | (AB*0.20)              |                   |                   |                   |                      | \$ 761,648   |
| AD. Engineering Services During Construction             | (AB*0.15)              |                   |                   |                   |                      | \$ 571,236   |
| AE. Construction Administration (CA)                     | (AB*0.04)              |                   |                   |                   |                      | \$ 152,330   |
| AF. Construction Inspection (CI)                         | (AB*0.07)              |                   |                   |                   |                      | \$ 266,577   |
| AG. Legal and Fiscal                                     | (AB*0.05)              |                   |                   |                   |                      | \$ 190,412   |
| AH. Owner Administration                                 | (AB*0.12)              |                   |                   |                   |                      | \$ 456,989   |
| CIP. Total Project Capital Cost                          | (AB+AC+AD+AE+AF+AG+AH) |                   |                   |                   |                      | \$ 6,207,433 |
| Operations/Maintenance                                   |                        |                   |                   |                   |                      |              |
| Operation                                                | Unit Rates             | Cost Units        | Annual Rates      | Annual Units      |                      |              |
| Building Energy                                          | 0.09                   | \$/kWh            | 1167              | kWh/yr            |                      | \$ 105       |
| Diesel                                                   |                        |                   |                   |                   |                      | \$ -         |
| Labor                                                    | 52                     | \$/hr             | 940               | hr/yr             |                      | \$ 48,875    |
| Media Replacement                                        | \$ 257,518             | \$/unit           | 4                 | units/20 yrs      |                      | \$ 51,504    |
| Natural Gas                                              |                        |                   |                   |                   |                      | \$ -         |
| Process Energy                                           | 0.09                   | \$/kWh            | 2796              | kWh/yr            |                      | \$ 252       |
| Subtotal (O&M)                                           |                        |                   |                   |                   |                      | \$ 100,736   |
| Chemicals                                                |                        |                   |                   |                   |                      |              |
| Chemical Name                                            | Chemical Cost          | Cost Units        | Amount            | Consumption Units |                      | Cost         |
| Subtotal (Chemical)                                      |                        |                   |                   |                   |                      | \$ -         |
| Air-Water Backwash System                                |                        |                   |                   |                   |                      |              |
| Process Size                                             |                        |                   |                   |                   |                      |              |
| Base Property                                            | Units                  | Min of Cost Range | Max of Cost Range | Design Cost Basis | Operating Cost Basis |              |
| area                                                     | ft²                    | 0                 | 0                 | 2400              | 2400                 |              |
| Construction Costs                                       |                        |                   |                   |                   |                      |              |
| Base Cost                                                | Equipment              | Labor             | Material          | Other             | Subcontract          | Subtotal     |
| Labor                                                    |                        |                   |                   |                   |                      | \$ 45,500    |
| Equipment                                                |                        |                   |                   |                   |                      | \$ 166,000   |
| Pipe & Valves                                            |                        |                   |                   |                   |                      | \$ 140,000   |
| A. Subtotal                                              |                        |                   |                   |                   |                      | \$ 351,500   |
| Additions/Contingency                                    |                        |                   |                   |                   |                      |              |
| Items                                                    | Formula                |                   |                   |                   |                      | Cost         |
| B. Miscellaneous and Unidentified Site Structures        | (A*0.25)               |                   |                   |                   |                      | \$ 87,875    |
| C. Unit Process Subtotal                                 | (A+B)                  |                   |                   |                   |                      | \$ 439,375   |
| D. Sitework                                              | (C*0.15)               |                   |                   |                   |                      | \$ 65,906    |
| E. Demolition                                            | (C*0)                  |                   |                   |                   |                      | \$ -         |
| F. I&C (SCADA)                                           | (C*0.08)               |                   |                   |                   |                      | \$ 35,150    |
| G. Site Electrical                                       | (C*0.10)               |                   |                   |                   |                      | \$ 43,938    |
| H. Large Piping and Specialty piping                     | (C*0.05)               |                   |                   |                   |                      | \$ 21,969    |
| J. Soil Conditions (Geotechnical requirements)           | (C*0.07)               |                   |                   |                   |                      | \$ 30,756    |
| K. Field General Conditions                              | (C*0.07)               |                   |                   |                   |                      | \$ 30,756    |
| L. Mobilization and Demobilization                       | (C*0.05)               |                   |                   |                   |                      | \$ 21,969    |
| M. Construction Subtotal (excluding miscellaneous items) | (C+D+E+F+G+H+J+K+L)    |                   |                   |                   |                      | \$ 689,819   |
| N. Miscellaneous Elements not Itemized                   | (M*0.2)                |                   |                   |                   |                      | \$ 137,964   |
| P. Non-Construction Fees                                 | (P)                    |                   |                   |                   |                      | \$ -         |
| R. Construction Subtotal (including miscellaneous items) | (M+N+P)                |                   |                   |                   |                      | \$ 827,783   |
| S. Sales Tax                                             | (R*0.094)              |                   |                   |                   |                      | \$ 77,812    |
| T. General Contractor OH and Profit                      | ((R+S)*0.15)           |                   |                   |                   |                      | \$ 135,839   |

|                                                          |                        |                          |                          |                          |                             |                 |
|----------------------------------------------------------|------------------------|--------------------------|--------------------------|--------------------------|-----------------------------|-----------------|
| U. Bonds and Insurance                                   | ((R+S+T)*0.035)        |                          |                          |                          |                             | \$ 36,450       |
| V. Construction Price Today                              | (R+S+T+U)              |                          |                          |                          |                             | \$ 1,077,883    |
| W. Projection to Mid-point of Construction               | (V*0)                  |                          |                          |                          |                             | \$ -            |
| X. Market adjustment factor                              | (V*0)                  |                          |                          |                          |                             | \$ -            |
| Y. Location adjustment factor                            | (V*0)                  |                          |                          |                          |                             | \$ -            |
| Z. Construction Bid Price                                | (V+W+X+Y)              |                          |                          |                          |                             | \$ 1,077,883    |
| AA. Undesigned Contingency                               | (Z*0.35)               |                          |                          |                          |                             | \$ 377,259      |
| AB. Construction Budget Price                            | (Z+AA)                 |                          |                          |                          |                             | \$ 1,455,142    |
| AC. Engineering Design Services                          | (AB*0.20)              |                          |                          |                          |                             | \$ 291,028      |
| AD. Engineering Services During Construction             | (AB*0.15)              |                          |                          |                          |                             | \$ 218,271      |
| AE. Construction Administration (CA)                     | (AB*0.04)              |                          |                          |                          |                             | \$ 58,206       |
| AF. Construction Inspection (CI)                         | (AB*0.07)              |                          |                          |                          |                             | \$ 101,860      |
| AG. Legal and Fiscal                                     | (AB*0.05)              |                          |                          |                          |                             | \$ 72,757       |
| AH. Owner Administration                                 | (AB*0.12)              |                          |                          |                          |                             | \$ 174,617      |
| CIP. Total Project Capital Cost                          | (AB+AC+AD+AE+AF+AG+AH) |                          |                          |                          |                             | \$ 2,371,882    |
| <b>Operations/Maintenance</b>                            |                        |                          |                          |                          |                             |                 |
| <b>Operation</b>                                         | <b>Unit Rates</b>      | <b>Cost Units</b>        | <b>Annual Rates</b>      | <b>Annual Units</b>      |                             |                 |
| Building Energy                                          |                        |                          |                          |                          |                             | \$ -            |
| Diesel                                                   |                        |                          |                          |                          |                             | \$ -            |
| Labor                                                    |                        | 52 \$/hr                 |                          | 266 hr/yr                |                             | \$ 13,830       |
| Materials                                                |                        | 1 \$                     | \$ 30                    | \$/yr                    |                             | \$ 5,706        |
| Natural Gas                                              |                        |                          |                          |                          |                             | \$ -            |
| Process Energy                                           |                        | 0.09 \$/kWh              |                          | 58104 kWh/yr             |                             | \$ 5,229        |
| Subtotal (O&M)                                           |                        |                          |                          |                          |                             | \$ 24,765       |
| <b>Chemicals</b>                                         |                        |                          |                          |                          |                             |                 |
| <b>Chemical Name</b>                                     | <b>Chemical Cost</b>   | <b>Cost Units</b>        | <b>Amount</b>            | <b>Consumption Units</b> |                             | <b>Cost</b>     |
| Subtotal (Chemical)                                      |                        |                          |                          |                          |                             | \$ -            |
| <b>Ozone System</b>                                      |                        |                          |                          |                          |                             |                 |
| <b>Process Size</b>                                      |                        |                          |                          |                          |                             |                 |
| <b>Base Property</b>                                     | <b>Units</b>           | <b>Min of Cost Range</b> | <b>Max of Cost Range</b> | <b>Design Cost Basis</b> | <b>Operating Cost Basis</b> |                 |
| mass flow                                                | lb/hr                  | 0                        | 0                        | 4                        | 4                           |                 |
| <b>Construction Costs</b>                                |                        |                          |                          |                          |                             |                 |
| <b>Base Cost</b>                                         | <b>Equipment</b>       | <b>Labor</b>             | <b>Material</b>          | <b>Other</b>             | <b>Subcontract</b>          | <b>Subtotal</b> |
| Housing                                                  |                        |                          |                          |                          |                             | \$ 54,320       |
| Labor                                                    |                        |                          |                          |                          |                             | \$ 8,220        |
| Ozone destruct system                                    |                        |                          |                          |                          |                             | \$ 108,640      |
| Ozone Generator                                          |                        |                          |                          |                          |                             | \$ 217,281      |
| Cooling Water System                                     |                        |                          |                          |                          |                             | \$ 108,640      |
| Mass Transfer System                                     |                        |                          |                          |                          |                             | \$ 217,281      |
| Liquid Oxygen Equipment                                  |                        |                          |                          |                          |                             | \$ 162,960      |
| A. Subtotal                                              |                        |                          |                          |                          |                             | \$ 877,342      |
| <b>Additions/Contingency</b>                             |                        |                          |                          |                          |                             |                 |
| <b>Items</b>                                             | <b>Formula</b>         |                          |                          |                          |                             | <b>Cost</b>     |
| B. Miscellaneous and Unidentified Site Structures        | (A*0.25)               |                          |                          |                          |                             | \$ 219,336      |
| C. Unit Process Subtotal                                 | (A+B)                  |                          |                          |                          |                             | \$ 1,096,678    |
| D. Sitework                                              | (C*0.15)               |                          |                          |                          |                             | \$ 164,502      |
| E. Demolition                                            | (C*0)                  |                          |                          |                          |                             | \$ -            |
| F. I&C (SCADA)                                           | (C*0.08)               |                          |                          |                          |                             | \$ 87,734       |
| G. Site Electrical                                       | (C*10)                 |                          |                          |                          |                             | \$ 109,668      |
| H. Large Piping and Specialty piping                     | (C*0.05)               |                          |                          |                          |                             | \$ 54,834       |
| J. Soil Conditions (Geotechnical requirements)           | (C*0.07)               |                          |                          |                          |                             | \$ 76,767       |
| K. Field General Conditions                              | (C*0.07)               |                          |                          |                          |                             | \$ 76,767       |
| L. Mobilization and Demobilization                       | (C*0.05)               |                          |                          |                          |                             | \$ 54,834       |
| M. Construction Subtotal (excluding miscellaneous items) | (C+D+E+F+G+H+J+K+L)    |                          |                          |                          |                             | \$ 1,721,784    |
| N. Miscellaneous Elements not Itemized                   | (M*0.2)                |                          |                          |                          |                             | \$ 344,357      |
| P. Non-Construction Fees                                 | (P)                    |                          |                          |                          |                             | \$ -            |
| R. Construction Subtotal (including miscellaneous items) | (M+N+P)                |                          |                          |                          |                             | \$ 2,066,141    |
| S. Sales Tax                                             | (R*0.094)              |                          |                          |                          |                             | \$ 194,217      |
| T. General Contractor OH and Profit                      | ((R+S)*0.15)           |                          |                          |                          |                             | \$ 339,054      |
| U. Bonds and Insurance                                   | ((R+S+T)*0.035)        |                          |                          |                          |                             | \$ 90,979       |
| V. Construction Price Today                              | (R+S+T+U)              |                          |                          |                          |                             | \$ 2,690,391    |
| W. Projection to Mid-point of Construction               | (V*0)                  |                          |                          |                          |                             | \$ -            |
| X. Market adjustment factor                              | (V*0)                  |                          |                          |                          |                             | \$ -            |
| Y. Location adjustment factor                            | (V*0)                  |                          |                          |                          |                             | \$ -            |
| Z. Construction Bid Price                                | (V+W+X+Y)              |                          |                          |                          |                             | \$ 2,690,391    |
| AA. Undesigned Contingency                               | (Z*0.35)               |                          |                          |                          |                             | \$ 941,637      |
| AB. Construction Budget Price                            | (Z+AA)                 |                          |                          |                          |                             | \$ 3,632,028    |
| AC. Engineering Design Services                          | (AB*0.20)              |                          |                          |                          |                             | \$ 726,406      |
| AD. Engineering Services During Construction             | (AB*0.15)              |                          |                          |                          |                             | \$ 544,804      |
| AE. Construction Administration (CA)                     | (AB*0.04)              |                          |                          |                          |                             | \$ 145,281      |
| AF. Construction Inspection (CI)                         | (AB*0.07)              |                          |                          |                          |                             | \$ 254,242      |
| AG. Legal and Fiscal                                     | (AB*0.05)              |                          |                          |                          |                             | \$ 181,601      |
| AH. Owner Administration                                 | (AB*0.12)              |                          |                          |                          |                             | \$ 435,843      |
| CIP. Total Project Capital Cost                          | (AB+AC+AD+AE+AF+AG+AH) |                          |                          |                          |                             | \$ 5,920,206    |
| <b>Operations/Maintenance</b>                            |                        |                          |                          |                          |                             |                 |
| <b>Operation</b>                                         | <b>Unit Rates</b>      | <b>Cost Units</b>        | <b>Annual Rates</b>      | <b>Annual Units</b>      |                             |                 |
| Building Energy                                          |                        | 0.09 \$/kWh              |                          | 24 kWh/yr                |                             | \$ 2            |
| Diesel                                                   |                        |                          |                          |                          |                             | \$ -            |
| Labor                                                    |                        | 52 \$/hr                 |                          | 304 hr/yr                |                             | \$ 15,783       |
| Materials                                                |                        | 1 \$                     | \$ 10                    | \$/yr                    |                             | \$ 1,987        |
| Natural Gas                                              |                        |                          |                          |                          |                             | \$ -            |
| Process Energy                                           |                        | 0.09 \$/kWh              |                          | 18039 kWh/yr             |                             | \$ 1,623        |
| Subtotal (O&M)                                           |                        |                          |                          |                          |                             | \$ 19,396       |
| <b>Chemicals</b>                                         |                        |                          |                          |                          |                             |                 |
| <b>Chemical Name</b>                                     | <b>Chemical Cost</b>   | <b>Cost Units</b>        | <b>Amount</b>            | <b>Consumption Units</b> |                             | <b>Cost</b>     |
| Subtotal (Chemical)                                      |                        |                          |                          |                          |                             | \$ -            |

# Ozone-BAC-GAC (5 MGD)

| GAC-BAC System                                           |                        |                   |                   |                   |                      |               |
|----------------------------------------------------------|------------------------|-------------------|-------------------|-------------------|----------------------|---------------|
| Process Size                                             |                        |                   |                   |                   |                      |               |
| Base Property                                            | Units                  | Min of Cost Range | Max of Cost Range | Design Cost Basis | Operating Cost Basis |               |
| contactor bed volume                                     | ft³                    | 0                 | 0                 | 30000             | 30000                |               |
| Construction Costs                                       |                        |                   |                   |                   |                      |               |
| Base Cost                                                | Equipment              | Labor             | Material          | Other             | Subcontract          | Subtotal      |
| Housing                                                  |                        |                   |                   |                   |                      | \$ 1,190,000  |
| Excavation & Sitework                                    |                        |                   |                   |                   |                      | \$ 5,690      |
| Labor                                                    |                        |                   |                   |                   |                      | \$ 193,000    |
| Equipment                                                |                        |                   |                   |                   |                      | \$ 869,000    |
| Media                                                    |                        |                   |                   |                   |                      | \$ 772,553    |
| Concrete                                                 |                        |                   |                   |                   |                      | \$ 23,000     |
| Steel                                                    |                        |                   |                   |                   |                      | \$ 13,400     |
| Pipe & Valves                                            |                        |                   |                   |                   |                      | \$ 293,000    |
| A. Subtotal                                              |                        |                   |                   |                   |                      | \$ 3,359,643  |
| Additions/Contingency                                    |                        |                   |                   |                   |                      |               |
| Items                                                    | Formula                |                   |                   |                   |                      | Cost          |
| B. Miscellaneous and Unidentified Site Structures        | (A*0.25)               |                   |                   |                   |                      | \$ 839,911    |
| C. Unit Process Subtotal                                 | (A+B)                  |                   |                   |                   |                      | \$ 4,199,554  |
| D. Sitework                                              | (C*0.15)               |                   |                   |                   |                      | \$ 629,933    |
| E. Demolition                                            | (C*0)                  |                   |                   |                   |                      | \$ -          |
| F. I&C (SCADA)                                           | (C*0.08)               |                   |                   |                   |                      | \$ 335,964    |
| G. Site Electrical                                       | (C*10)                 |                   |                   |                   |                      | \$ 419,955    |
| H. Large Piping and Specialty piping                     | (C*0.05)               |                   |                   |                   |                      | \$ 209,978    |
| J. Soil Conditions (Geotechnical requirements)           | (C*0.07)               |                   |                   |                   |                      | \$ 293,969    |
| K. Field General Conditions                              | (C*0.07)               |                   |                   |                   |                      | \$ 293,969    |
| L. Mobilization and Demobilization                       | (C*0.05)               |                   |                   |                   |                      | \$ 209,978    |
| M. Construction Subtotal (excluding miscellaneous items) | (C+D+E+F+G+H+J+K+L)    |                   |                   |                   |                      | \$ 6,593,300  |
| N. Miscellaneous Elements not Itemized                   | (M*0.2)                |                   |                   |                   |                      | \$ 1,318,660  |
| P. Non-Construction Fees                                 | (P)                    |                   |                   |                   |                      | \$ -          |
| R. Construction Subtotal (including miscellaneous items) | (M+N+P)                |                   |                   |                   |                      | \$ 7,911,960  |
| S. Sales Tax                                             | (R*0.094)              |                   |                   |                   |                      | \$ 743,724    |
| T. General Contractor OH and Profit                      | ((R+S)*0.15)           |                   |                   |                   |                      | \$ 1,298,353  |
| U. Bonds and Insurance                                   | ((R+S+T)*0.035)        |                   |                   |                   |                      | \$ 348,391    |
| V. Construction Price Today                              | (R+S+T+U)              |                   |                   |                   |                      | \$ 10,302,428 |
| W. Projection to Mid-point of Construction               | (V*0)                  |                   |                   |                   |                      | \$ -          |
| X. Market adjustment factor                              | (V*0)                  |                   |                   |                   |                      | \$ -          |
| Y. Location adjustment factor                            | (V*0)                  |                   |                   |                   |                      | \$ -          |
| Z. Construction Bid Price                                | (V+W+X+Y)              |                   |                   |                   |                      | \$ 10,302,428 |
| AA. Undesigned Contingency                               | (Z*0.35)               |                   |                   |                   |                      | \$ 3,605,850  |
| AB. Construction Budget Price                            | (Z+AA)                 |                   |                   |                   |                      | \$ 13,908,277 |
| AC. Engineering Design Services                          | (AB*0.20)              |                   |                   |                   |                      | \$ 2,781,655  |
| AD. Engineering Services During Construction             | (AB*0.15)              |                   |                   |                   |                      | \$ 2,086,242  |
| AE. Construction Administration (CA)                     | (AB*0.04)              |                   |                   |                   |                      | \$ 556,331    |
| AF. Construction Inspection (CI)                         | (AB*0.07)              |                   |                   |                   |                      | \$ 973,579    |
| AG. Legal and Fiscal                                     | (AB*0.05)              |                   |                   |                   |                      | \$ 695,414    |
| AH. Owner Administration                                 | (AB*0.12)              |                   |                   |                   |                      | \$ 1,668,993  |
| CIP. Total Project Capital Cost                          | (AB+AC+AD+AE+AF+AG+AH) |                   |                   |                   |                      | \$ 22,670,492 |
| Operations/Maintenance                                   |                        |                   |                   |                   |                      |               |
| Operation                                                | Unit Rates             | Cost Units        | Annual Rates      | Annual Units      |                      |               |
| Building Energy                                          | 0.09                   | \$/kWh            | 6942              | kWh/yr            |                      | \$ 625        |
| Diesel                                                   |                        |                   |                   |                   |                      | \$ -          |
| Labor                                                    | 52                     | \$/hr             | 2615              | hr/yr             |                      | \$ 135,997    |
| Media Replacement                                        | \$ 772,553             | \$/unit           | 4                 | units/ 20 yrs     |                      | \$ 154,511    |
| Natural Gas                                              |                        |                   |                   |                   |                      | \$ -          |
| Process Energy                                           | 0.09                   | \$/kWh            | 11494             | kWh/yr            |                      | \$ 1,034      |
| Subtotal (O&M)                                           |                        |                   |                   |                   |                      | \$ 292,167    |
| Chemicals                                                |                        |                   |                   |                   |                      |               |
| Chemical Name                                            | Chemical Cost          | Cost Units        | Amount            | Consumption Units |                      | Cost          |
| Subtotal (Chemical)                                      |                        |                   |                   |                   |                      | \$ -          |
| Air-Water Backwash System                                |                        |                   |                   |                   |                      |               |
| Process Size                                             |                        |                   |                   |                   |                      |               |
| Base Property                                            | Units                  | Min of Cost Range | Max of Cost Range | Design Cost Basis | Operating Cost Basis |               |
| area                                                     | ft²                    | 0                 | 0                 | 10000             | 10000                |               |
| Construction Costs                                       |                        |                   |                   |                   |                      |               |
| Base Cost                                                | Equipment              | Labor             | Material          | Other             | Subcontract          | Subtotal      |
| Labor                                                    |                        |                   |                   |                   |                      | \$ 81,900     |
| Equipment                                                |                        |                   |                   |                   |                      | \$ 264,000    |
| Pipe & Valves                                            |                        |                   |                   |                   |                      | \$ 313,000    |
| A. Subtotal                                              |                        |                   |                   |                   |                      | \$ 658,900    |
| Additions/Contingency                                    |                        |                   |                   |                   |                      |               |
| Items                                                    | Formula                |                   |                   |                   |                      | Cost          |
| B. Miscellaneous and Unidentified Site Structures        | (A*0.25)               |                   |                   |                   |                      | \$ 164,725    |
| C. Unit Process Subtotal                                 | (A+B)                  |                   |                   |                   |                      | \$ 823,625    |
| D. Sitework                                              | (C*0.15)               |                   |                   |                   |                      | \$ 123,544    |
| E. Demolition                                            | (C*0)                  |                   |                   |                   |                      | \$ -          |
| F. I&C (SCADA)                                           | (C*0.08)               |                   |                   |                   |                      | \$ 65,890     |
| G. Site Electrical                                       | (C*0.10)               |                   |                   |                   |                      | \$ 82,363     |
| H. Large Piping and Specialty piping                     | (C*0.05)               |                   |                   |                   |                      | \$ 41,181     |
| J. Soil Conditions (Geotechnical requirements)           | (C*0.07)               |                   |                   |                   |                      | \$ 57,654     |
| K. Field General Conditions                              | (C*0.07)               |                   |                   |                   |                      | \$ 57,654     |
| L. Mobilization and Demobilization                       | (C*0.05)               |                   |                   |                   |                      | \$ 41,181     |
| M. Construction Subtotal (excluding miscellaneous items) | (C+D+E+F+G+H+J+K+L)    |                   |                   |                   |                      | \$ 1,293,091  |
| N. Miscellaneous Elements not Itemized                   | (M*0.2)                |                   |                   |                   |                      | \$ 258,618    |
| P. Non-Construction Fees                                 | (P)                    |                   |                   |                   |                      | \$ -          |
| R. Construction Subtotal (including miscellaneous items) | (M+N+P)                |                   |                   |                   |                      | \$ 1,551,710  |
| S. Sales Tax                                             | (R*0.094)              |                   |                   |                   |                      | \$ 145,861    |
| T. General Contractor OH and Profit                      | ((R+S)*0.15)           |                   |                   |                   |                      | \$ 254,636    |

|                                                          |                        |                          |                          |                          |                             |                 |
|----------------------------------------------------------|------------------------|--------------------------|--------------------------|--------------------------|-----------------------------|-----------------|
| U. Bonds and Insurance                                   | ((R+S+T)*0.035)        |                          |                          |                          |                             | \$ 68,327       |
| V. Construction Price Today                              | (R+S+T+U)              |                          |                          |                          |                             | \$ 2,020,533    |
| W. Projection to Mid-point of Construction               | (V*0)                  |                          |                          |                          |                             | \$ -            |
| X. Market adjustment factor                              | (V*0)                  |                          |                          |                          |                             | \$ -            |
| Y. Location adjustment factor                            | (V*0)                  |                          |                          |                          |                             | \$ -            |
| Z. Construction Bid Price                                | (V+W+X+Y)              |                          |                          |                          |                             | \$ 2,020,533    |
| AA. Undesigned Contingency                               | (Z*0.35)               |                          |                          |                          |                             | \$ 707,187      |
| AB. Construction Budget Price                            | (Z+AA)                 |                          |                          |                          |                             | \$ 2,727,719    |
| AC. Engineering Design Services                          | (AB*0.20)              |                          |                          |                          |                             | \$ 545,544      |
| AD. Engineering Services During Construction             | (AB*0.15)              |                          |                          |                          |                             | \$ 409,158      |
| AE. Construction Administration (CA)                     | (AB*0.04)              |                          |                          |                          |                             | \$ 109,109      |
| AF. Construction Inspection (CI)                         | (AB*0.07)              |                          |                          |                          |                             | \$ 190,940      |
| AG. Legal and Fiscal                                     | (AB*0.05)              |                          |                          |                          |                             | \$ 136,386      |
| AH. Owner Administration                                 | (AB*0.12)              |                          |                          |                          |                             | \$ 327,326      |
| CIP. Total Project Capital Cost                          | (AB+AC+AD+AE+AF+AG+AH) |                          |                          |                          |                             | \$ 4,446,183    |
| <b>Operations/Maintenance</b>                            |                        |                          |                          |                          |                             |                 |
| <b>Operation</b>                                         | <b>Unit Rates</b>      | <b>Cost Units</b>        | <b>Annual Rates</b>      | <b>Annual Units</b>      |                             |                 |
| Building Energy                                          |                        |                          |                          |                          |                             | \$ -            |
| Diesel                                                   |                        |                          |                          |                          |                             | \$ -            |
| Labor                                                    |                        | 52 \$/hr                 |                          | 322 hr/yr                |                             | \$ 16,745       |
| Materials                                                |                        | 1 \$                     |                          | 53 \$/yr                 |                             | \$ 10,187       |
| Natural Gas                                              |                        |                          |                          |                          |                             | \$ -            |
| Process Energy                                           |                        | 0.09 \$/kWh              |                          | 242203 kWh/yr            |                             | \$ 21,798       |
| Subtotal (O&M)                                           |                        |                          |                          |                          |                             | \$ 48,731       |
| <b>Chemicals</b>                                         |                        |                          |                          |                          |                             |                 |
| <b>Chemical Name</b>                                     | <b>Chemical Cost</b>   | <b>Cost Units</b>        | <b>Amount</b>            | <b>Consumption Units</b> |                             | <b>Cost</b>     |
| Subtotal (Chemical)                                      |                        |                          |                          |                          |                             | \$ -            |
| <b>Ozone System</b>                                      |                        |                          |                          |                          |                             |                 |
| <b>Process Size</b>                                      |                        |                          |                          |                          |                             |                 |
| <b>Base Property</b>                                     | <b>Units</b>           | <b>Min of Cost Range</b> | <b>Max of Cost Range</b> | <b>Design Cost Basis</b> | <b>Operating Cost Basis</b> |                 |
| mass flow                                                | lb/hr                  | 0                        | 0                        | 22                       | 22                          |                 |
| <b>Construction Costs</b>                                |                        |                          |                          |                          |                             |                 |
| <b>Base Cost</b>                                         | <b>Equipment</b>       | <b>Labor</b>             | <b>Material</b>          | <b>Other</b>             | <b>Subcontract</b>          | <b>Subtotal</b> |
| Building                                                 |                        |                          |                          |                          |                             | \$ 98,078       |
| Labor                                                    |                        |                          |                          |                          |                             | \$ 31,100       |
| Ozone destruct system                                    |                        |                          |                          |                          |                             | \$ 196,156      |
| Ozone Generator                                          |                        |                          |                          |                          |                             | \$ 392,312      |
| Cooling Water System                                     |                        |                          |                          |                          |                             | \$ 196,156      |
| Mass Transfer System                                     |                        |                          |                          |                          |                             | \$ 392,312      |
| Liquid Oxygen Equipment                                  |                        |                          |                          |                          |                             | \$ 294,234      |
| A. Subtotal                                              |                        |                          |                          |                          |                             | \$ 1,600,349    |
| <b>Additions/Contingency</b>                             |                        |                          |                          |                          |                             |                 |
| <b>Items</b>                                             | <b>Formula</b>         |                          |                          |                          |                             | <b>Cost</b>     |
| B. Miscellaneous and Unidentified Site Structures        | (A*0.25)               |                          |                          |                          |                             | \$ 400,087      |
| C. Unit Process Subtotal                                 | (A+B)                  |                          |                          |                          |                             | \$ 2,000,436    |
| D. Sitework                                              | (C*0.15)               |                          |                          |                          |                             | \$ 300,065      |
| E. Demolition                                            | (C*0)                  |                          |                          |                          |                             | \$ -            |
| F. I&C (SCADA)                                           | (C*0.08)               |                          |                          |                          |                             | \$ 160,035      |
| G. Site Electrical                                       | (C*0.10)               |                          |                          |                          |                             | \$ 200,044      |
| H. Large Piping and Specialty piping                     | (C*0.05)               |                          |                          |                          |                             | \$ 100,022      |
| J. Soil Conditions (Geotechnical requirements)           | (C*0.07)               |                          |                          |                          |                             | \$ 140,030      |
| K. Field General Conditions                              | (C*0.07)               |                          |                          |                          |                             | \$ 140,030      |
| L. Mobilization and Demobilization                       | (C*0.05)               |                          |                          |                          |                             | \$ 100,022      |
| M. Construction Subtotal (excluding miscellaneous items) | (C+D+E+F+G+H+J+K+L)    |                          |                          |                          |                             | \$ 3,140,684    |
| N. Miscellaneous Elements not Itemized                   | (M*0.2)                |                          |                          |                          |                             | \$ 628,137      |
| P. Non-Construction Fees                                 | (P)                    |                          |                          |                          |                             | \$ -            |
| R. Construction Subtotal (including miscellaneous items) | (M+N+P)                |                          |                          |                          |                             | \$ 3,768,821    |
| S. Sales Tax                                             | (R*0.094)              |                          |                          |                          |                             | \$ 354,269      |
| T. General Contractor OH and Profit                      | ((R+S)*0.15)           |                          |                          |                          |                             | \$ 618,463      |
| U. Bonds and Insurance                                   | ((R+S+T)*0.035)        |                          |                          |                          |                             | \$ 165,954      |
| V. Construction Price Today                              | (R+S+T+U)              |                          |                          |                          |                             | \$ 4,907,508    |
| W. Projection to Mid-point of Construction               | (V*0)                  |                          |                          |                          |                             | \$ -            |
| X. Market adjustment factor                              | (V*0)                  |                          |                          |                          |                             | \$ -            |
| Y. Location adjustment factor                            | (V*0)                  |                          |                          |                          |                             | \$ -            |
| Z. Construction Bid Price                                | (V+W+X+Y)              |                          |                          |                          |                             | \$ 4,907,508    |
| AA. Undesigned Contingency                               | (Z*0.35)               |                          |                          |                          |                             | \$ 1,717,628    |
| AB. Construction Budget Price                            | (Z+AA)                 |                          |                          |                          |                             | \$ 6,625,135    |
| AC. Engineering Design Services                          | (AB*0.20)              |                          |                          |                          |                             | \$ 1,325,027    |
| AD. Engineering Services During Construction             | (AB*0.15)              |                          |                          |                          |                             | \$ 993,770      |
| AE. Construction Administration (CA)                     | (AB*0.04)              |                          |                          |                          |                             | \$ 265,005      |
| AF. Construction Inspection (CI)                         | (AB*0.07)              |                          |                          |                          |                             | \$ 463,759      |
| AG. Legal and Fiscal                                     | (AB*0.05)              |                          |                          |                          |                             | \$ 331,257      |
| AH. Owner Administration                                 | (AB*0.12)              |                          |                          |                          |                             | \$ 795,016      |
| CIP. Total Project Capital Cost                          | (AB+AC+AD+AE+AF+AG+AH) |                          |                          |                          |                             | \$ 10,798,971   |
| <b>Operations/Maintenance</b>                            |                        |                          |                          |                          |                             |                 |
| <b>Operation</b>                                         | <b>Unit Rates</b>      | <b>Cost Units</b>        | <b>Annual Rates</b>      | <b>Annual Units</b>      |                             |                 |
| Building Energy                                          |                        | 0.09 \$/kWh              |                          | 57 kWh/yr                |                             | \$ 5            |
| Diesel                                                   |                        |                          |                          |                          |                             | \$ -            |
| Labor                                                    |                        | 52 \$/hr                 |                          | 509 hr/yr                |                             | \$ 26,454       |
| Materials                                                |                        | 1 \$                     |                          | 26 \$/yr                 |                             | \$ 5,017        |
| Natural Gas                                              |                        |                          |                          |                          |                             | \$ -            |
| Process Energy                                           |                        | 0.09 \$/kWh              |                          | 86396 kWh/yr             |                             | \$ 7,776        |
| Subtotal (O&M)                                           |                        |                          |                          |                          |                             | \$ 39,252       |
| <b>Chemicals</b>                                         |                        |                          |                          |                          |                             |                 |
| <b>Chemical Name</b>                                     | <b>Chemical Cost</b>   | <b>Cost Units</b>        | <b>Amount</b>            | <b>Consumption Units</b> |                             | <b>Cost</b>     |
| Subtotal (Chemical)                                      |                        |                          |                          |                          |                             | \$ -            |

# GAC (1 MGD)

| GAC System                                               |                        |                   |                   |                   |                      |              |
|----------------------------------------------------------|------------------------|-------------------|-------------------|-------------------|----------------------|--------------|
| Process Size                                             |                        |                   |                   |                   |                      |              |
| Base Property                                            | Units                  | Min of Cost Range | Max of Cost Range | Design Cost Basis | Operating Cost Basis |              |
| contactor bed volume                                     | ft³                    | 0                 | 0                 | 7300              | 7300                 |              |
| Construction Costs                                       |                        |                   |                   |                   |                      |              |
| Base Cost                                                | Equipment              | Labor             | Material          | Other             | Subcontract          | Subtotal     |
| Building                                                 |                        |                   |                   |                   |                      | \$ 151,500   |
| Excavation & Sitework                                    |                        |                   |                   |                   |                      | \$ 1,890     |
| Labor                                                    |                        |                   |                   |                   |                      | \$ 51,500    |
| Equipment                                                |                        |                   |                   |                   |                      | \$ 222,000   |
| Media                                                    |                        |                   |                   |                   |                      | \$ 257,518   |
| Concrete                                                 |                        |                   |                   |                   |                      | \$ 7,220     |
| Steel                                                    |                        |                   |                   |                   |                      | \$ 4,180     |
| Pipe & Valves                                            |                        |                   |                   |                   |                      | \$ 72,600    |
| Electrical & Instrumentation                             |                        |                   |                   |                   |                      | \$ 54,600    |
| A. Subtotal                                              |                        |                   |                   |                   |                      | \$ 411,500   |
| Additions/Contingency                                    |                        |                   |                   |                   |                      |              |
| Items                                                    | Formula                |                   |                   |                   |                      | Cost         |
| B. Miscellaneous and Unidentified Site Structures        | (A*0.25)               |                   |                   |                   |                      | \$ 102,876   |
| C. Unit Process Subtotal                                 | (A+B)                  |                   |                   |                   |                      | \$ 514,380   |
| D. Sitework                                              | (C*0.15)               |                   |                   |                   |                      | \$ 77,157    |
| E. Demolition                                            | (C*0.01)               |                   |                   |                   |                      | \$ -         |
| F. I&C (SCADA)                                           | (C*0.08)               |                   |                   |                   |                      | \$ 41,150    |
| G. Site Electrical                                       | (C*10)                 |                   |                   |                   |                      | \$ 51,438    |
| H. Large Piping and Specialty piping                     | (C*0.05)               |                   |                   |                   |                      | \$ 25,719    |
| J. Soil Conditions (Geotechnical requirements)           | (C*0.07)               |                   |                   |                   |                      | \$ 36,007    |
| K. Field General Conditions                              | (C*0.07)               |                   |                   |                   |                      | \$ 36,007    |
| L. Mobilization and Demobilization                       | (C*0.05)               |                   |                   |                   |                      | \$ 25,719    |
| M. Construction Subtotal (excluding miscellaneous items) | (C+D+E+F+G+H+J+K+L)    |                   |                   |                   |                      | \$ 807,576   |
| N. Miscellaneous Elements not Itemized                   | (M*0.2)                |                   |                   |                   |                      | \$ 161,515   |
| P. Non-Construction Fees                                 | (P)                    |                   |                   |                   |                      | \$ -         |
| R. Construction Subtotal (including miscellaneous items) | (M+N+P)                |                   |                   |                   |                      | \$ 969,092   |
| S. Sales Tax                                             | (R*0.094)              |                   |                   |                   |                      | \$ 91,095    |
| T. General Contractor OH and Profit                      | ((R+S)*0.15)           |                   |                   |                   |                      | \$ 159,028   |
| U. Bonds and Insurance                                   | ((R+S+T)*0.035)        |                   |                   |                   |                      | \$ 42,672    |
| V. Construction Price Today                              | (R+S+T+U)              |                   |                   |                   |                      | \$ 1,261,887 |
| W. Projection to Mid-point of Construction               | (V*0)                  |                   |                   |                   |                      | \$ -         |
| X. Market adjustment factor                              | (V*0)                  |                   |                   |                   |                      | \$ -         |
| Y. Location adjustment factor                            | (V*0)                  |                   |                   |                   |                      | \$ -         |
| Z. Construction Bid Price                                | (V+W+X+Y)              |                   |                   |                   |                      | \$ 1,261,887 |
| AA. Undesigned Contingency                               | (Z*0.35)               |                   |                   |                   |                      | \$ 441,660   |
| AB. Construction Budget Price                            | (Z+AA)                 |                   |                   |                   |                      | \$ 1,703,547 |
| AC. Engineering Design Services                          | (AB*0.20)              |                   |                   |                   |                      | \$ 340,709   |
| AD. Engineering Services During Construction             | (AB*0.15)              |                   |                   |                   |                      | \$ 255,532   |
| AE. Construction Administration (CA)                     | (AB*0.04)              |                   |                   |                   |                      | \$ 68,142    |
| AF. Construction Inspection (CI)                         | (AB*0.07)              |                   |                   |                   |                      | \$ 119,248   |
| AG. Legal and Fiscal                                     | (AB*0.05)              |                   |                   |                   |                      | \$ 85,177    |
| AH. Owner Administration                                 | (AB*0.12)              |                   |                   |                   |                      | \$ 204,426   |
| CIP. Total Project Capital Cost                          | (AB+AC+AD+AE+AF+AG+AH) |                   |                   |                   |                      | \$ 2,776,781 |
| Operations/Maintenance                                   |                        |                   |                   |                   |                      |              |
| Operation                                                | Unit Rates             | Cost Units        | Annual Rates      | Annual Units      |                      |              |
| Building Energy                                          | 0.09                   | \$/kWh            | 1167              | kWh/yr            |                      | \$ 105       |
| Diesel                                                   |                        |                   |                   |                   |                      | \$ -         |
| Labor                                                    | 52                     | \$/hr             | 470               | hr/yr             |                      | \$ 24,438    |
| Media Replacement                                        | \$ 257,518             | \$/unit           | 4                 | units/20 yrs      |                      | \$ 25,752    |
| Natural Gas                                              |                        |                   |                   |                   |                      | \$ -         |
| Process Energy                                           | 0.09                   | \$/kWh            | 2796              | kWh/yr            |                      | \$ 252       |
| Subtotal (O&M)                                           |                        |                   |                   |                   |                      | \$ 50,546    |
| Chemicals                                                |                        |                   |                   |                   |                      |              |
| Chemical Name                                            | Chemical Cost          | Cost Units        | Amount            | Consumption Units |                      | Cost         |
| Subtotal (Chemical)                                      |                        |                   |                   |                   |                      | \$ -         |
| Air-Water Backwash System                                |                        |                   |                   |                   |                      |              |
| Process Size                                             |                        |                   |                   |                   |                      |              |
| Base Property                                            | Units                  | Min of Cost Range | Max of Cost Range | Design Cost Basis | Operating Cost Basis |              |
| area                                                     | ft²                    | 0                 | 0                 | 2400              | 2400                 |              |
| Construction Costs                                       |                        |                   |                   |                   |                      |              |
| Base Cost                                                | Equipment              | Labor             | Material          | Other             | Subcontract          | Subtotal     |
| Labor                                                    |                        |                   |                   |                   |                      | \$ 45,500    |
| Equipment                                                |                        |                   |                   |                   |                      | \$ 166,000   |
| Pipe & Valves                                            |                        |                   |                   |                   |                      | \$ 140,000   |
| Electrical & Instrumentation                             |                        |                   |                   |                   |                      | \$ 84,900    |
| A. Subtotal                                              |                        |                   |                   |                   |                      | \$ 218,200   |
| Additions/Contingency                                    |                        |                   |                   |                   |                      |              |
| Items                                                    | Formula                |                   |                   |                   |                      | Cost         |
| B. Miscellaneous and Unidentified Site Structures        | (A*0.25)               |                   |                   |                   |                      | \$ 54,550    |
| C. Unit Process Subtotal                                 | (A+B)                  |                   |                   |                   |                      | \$ 272,750   |
| D. Sitework                                              | (C*0.15)               |                   |                   |                   |                      | \$ 40,913    |
| E. Demolition                                            | (C*0)                  |                   |                   |                   |                      | \$ -         |
| F. I&C (SCADA)                                           | (C*0.08)               |                   |                   |                   |                      | \$ 21,820    |
| G. Site Electrical                                       | (C*0.10)               |                   |                   |                   |                      | \$ 27,275    |
| H. Large Piping and Specialty piping                     | (C*0.05)               |                   |                   |                   |                      | \$ 13,638    |
| J. Soil Conditions (Geotechnical requirements)           | (C*0.07)               |                   |                   |                   |                      | \$ 19,093    |
| K. Field General Conditions                              | (C*0.07)               |                   |                   |                   |                      | \$ 19,093    |
| L. Mobilization and Demobilization                       | (C*0.05)               |                   |                   |                   |                      | \$ 13,638    |
| M. Construction Subtotal (excluding miscellaneous items) | (C+D+E+F+G+H+J+K+L)    |                   |                   |                   |                      | \$ 428,218   |
| N. Miscellaneous Elements not Itemized                   | (M*0)                  |                   |                   |                   |                      | \$ 85,644    |
| P. Non-Construction Fees                                 | (P)                    |                   |                   |                   |                      | \$ -         |
| R. Construction Subtotal (including miscellaneous items) | (M+N+P)                |                   |                   |                   |                      | \$ 513,861   |
| S. Sales Tax                                             | (R*0.094)              |                   |                   |                   |                      | \$ 48,303    |

|                                              |                          |                   |                     |                          |  |              |
|----------------------------------------------|--------------------------|-------------------|---------------------|--------------------------|--|--------------|
| T. General Contractor OH and Profit          | $((R+S)*0.15)$           |                   |                     |                          |  | \$ 84,325    |
| U. Bonds and Insurance                       | $((R+S+T)*0.035)$        |                   |                     |                          |  | \$ 22,627    |
| V. Construction Price Today                  | $(R+S+T+U)$              |                   |                     |                          |  | \$ 669,116   |
| W. Projection to Mid-point of Construction   | $(V*0)$                  |                   |                     |                          |  | \$ -         |
| X. Market adjustment factor                  | $(V*0)$                  |                   |                     |                          |  | \$ -         |
| Y. Location adjustment factor                | $(V*0)$                  |                   |                     |                          |  | \$ -         |
| Z. Construction Bid Price                    | $(V+W+X+Y)$              |                   |                     |                          |  | \$ 669,116   |
| AA. Undesigned Contingency                   | $(Z*0.35)$               |                   |                     |                          |  | \$ 234,190   |
| AB. Construction Budget Price                | $(Z+AA)$                 |                   |                     |                          |  | \$ 903,306   |
| AC. Engineering Design Services              | $(AB*0.175)$             |                   |                     |                          |  | \$ 180,661   |
| AD. Engineering Services During Construction | $(AB*0.075)$             |                   |                     |                          |  | \$ 135,496   |
| AE. Construction Administration (CA)         | $(AB*0.04)$              |                   |                     |                          |  | \$ 36,132    |
| AF. Construction Inspection (CI)             | $(AB*0.07)$              |                   |                     |                          |  | \$ 63,231    |
| AG. Legal and Fiscal                         | $(AB*0.05)$              |                   |                     |                          |  | \$ 45,165    |
| AH. Owner Administration                     | $(AB*0.12)$              |                   |                     |                          |  | \$ 108,397   |
| CIP. Total Project Capital Cost              | $(AB+AC+AD+AE+AF+AG+AH)$ |                   |                     |                          |  | \$ 1,472,389 |
| <b>Operations/Maintenance</b>                |                          |                   |                     |                          |  |              |
| <b>Operation</b>                             | <b>Unit Rates</b>        | <b>Cost Units</b> | <b>Annual Rates</b> | <b>Annual Units</b>      |  |              |
| Building Energy                              |                          |                   |                     |                          |  | \$ -         |
| Diesel                                       |                          |                   |                     |                          |  | \$ -         |
| Labor                                        | 52 \$/hr                 |                   | 266 hr/yr           |                          |  | \$ 13,830    |
| Materials                                    | 1 \$                     |                   | 30 \$/yr            |                          |  | \$ 5,706     |
| Natural Gas                                  |                          |                   |                     |                          |  | \$ -         |
| Process Energy                               | 0.09 \$/kWh              |                   | 58104 kWh/yr        |                          |  | \$ 5,229     |
| Subtotal (O&M)                               |                          |                   |                     |                          |  | \$ 24,765    |
| <b>Chemicals</b>                             |                          |                   |                     |                          |  |              |
| <b>Chemical Name</b>                         | <b>Chemical Cost</b>     | <b>Cost Units</b> | <b>Amount</b>       | <b>Consumption Units</b> |  | <b>Cost</b>  |
| Subtotal (Chemical)                          |                          |                   |                     |                          |  | \$ -         |

# GAC (5 MGD)

| GAC System                                               |                        |                   |                   |                   |                      |               |
|----------------------------------------------------------|------------------------|-------------------|-------------------|-------------------|----------------------|---------------|
| Process Size                                             |                        |                   |                   |                   |                      |               |
| Base Property                                            | Units                  | Min of Cost Range | Max of Cost Range | Design Cost Basis | Operating Cost Basis |               |
| contactor bed volume                                     | ft³                    | 0                 | 0                 | 30000             | 30000                |               |
| Construction Costs                                       |                        |                   |                   |                   |                      |               |
| Base Cost                                                | Equipment              | Labor             | Material          | Other             | Subcontract          | Subtotal      |
| Building                                                 |                        |                   |                   |                   |                      | \$ 1,190,000  |
| Excavation & Sitework                                    |                        |                   |                   |                   |                      | \$ 5,690      |
| Labor                                                    |                        |                   |                   |                   |                      | \$ 193,000    |
| Equipment                                                |                        |                   |                   |                   |                      | \$ 869,000    |
| Media                                                    |                        |                   |                   |                   |                      | \$ 772,553    |
| Concrete                                                 |                        |                   |                   |                   |                      | \$ 23,000     |
| Steel                                                    |                        |                   |                   |                   |                      | \$ 13,400     |
| Pipe & Valves                                            |                        |                   |                   |                   |                      | \$ 293,000    |
| Electrical & Instrumentation                             |                        |                   |                   |                   |                      | \$ 199,000    |
| A. Subtotal                                              |                        |                   |                   |                   |                      | \$ 1,779,322  |
| Additions/Contingency                                    |                        |                   |                   |                   |                      |               |
| Items                                                    | Formula                |                   |                   |                   |                      | Cost          |
| B. Miscellaneous and Unidentified Site Structures        | (A*0.25)               |                   |                   |                   |                      | \$ 444,830    |
| C. Unit Process Subtotal                                 | (A+B)                  |                   |                   |                   |                      | \$ 2,224,152  |
| D. Sitework                                              | (C*0.15)               |                   |                   |                   |                      | \$ 333,623    |
| E. Demolition                                            | (C*0)                  |                   |                   |                   |                      | \$ -          |
| F. I&C (SCADA)                                           | (C*0.08)               |                   |                   |                   |                      | \$ 177,932    |
| G. Site Electrical                                       | (C*10)                 |                   |                   |                   |                      | \$ 222,415    |
| H. Large Piping and Specialty piping                     | (C*0.05)               |                   |                   |                   |                      | \$ 111,208    |
| J. Soil Conditions (Geotechnical requirements)           | (C*0.07)               |                   |                   |                   |                      | \$ 155,691    |
| K. Field General Conditions                              | (C*0.07)               |                   |                   |                   |                      | \$ 155,691    |
| L. Mobilization and Demobilization                       | (C*0.05)               |                   |                   |                   |                      | \$ 111,208    |
| M. Construction Subtotal (excluding miscellaneous items) | (C+D+E+F+G+H+J+K+L)    |                   |                   |                   |                      | \$ 3,491,919  |
| N. Miscellaneous Elements not Itemized                   | (M*0.2)                |                   |                   |                   |                      | \$ 698,384    |
| P. Non-Construction Fees                                 | (P)                    |                   |                   |                   |                      | \$ -          |
| R. Construction Subtotal (including miscellaneous items) | (M+N+P)                |                   |                   |                   |                      | \$ 4,190,302  |
| S. Sales Tax                                             | (R*0.094)              |                   |                   |                   |                      | \$ 393,888    |
| T. General Contractor OH and Profit                      | ((R+S)*0.15)           |                   |                   |                   |                      | \$ 687,629    |
| U. Bonds and Insurance                                   | ((R+S+T)*0.035)        |                   |                   |                   |                      | \$ 184,514    |
| V. Construction Price Today                              | (R+S+T+U)              |                   |                   |                   |                      | \$ 5,456,333  |
| W. Projection to Mid-point of Construction               | (V*0)                  |                   |                   |                   |                      | \$ -          |
| X. Market adjustment factor                              | (V*0)                  |                   |                   |                   |                      | \$ -          |
| Y. Location adjustment factor                            | (V*0)                  |                   |                   |                   |                      | \$ -          |
| Z. Construction Bid Price                                | (V+W+X+Y)              |                   |                   |                   |                      | \$ 5,456,333  |
| AA. Undesigned Contingency                               | (Z*0.35)               |                   |                   |                   |                      | \$ 1,909,717  |
| AB. Construction Budget Price                            | (Z+AA)                 |                   |                   |                   |                      | \$ 7,366,049  |
| AC. Engineering Design Services                          | (AB*0.20)              |                   |                   |                   |                      | \$ 1,473,210  |
| AD. Engineering Services During Construction             | (AB*0.15)              |                   |                   |                   |                      | \$ 1,104,907  |
| AE. Construction Administration (CA)                     | (AB*0.04)              |                   |                   |                   |                      | \$ 294,642    |
| AF. Construction Inspection (CI)                         | (AB*0.07)              |                   |                   |                   |                      | \$ 515,623    |
| AG. Legal and Fiscal                                     | (AB*0.05)              |                   |                   |                   |                      | \$ 368,302    |
| AH. Owner Administration                                 | (AB*0.12)              |                   |                   |                   |                      | \$ 883,926    |
| CIP. Total Project Capital Cost                          | (AB+AC+AD+AE+AF+AG+AH) |                   |                   |                   |                      | \$ 12,006,661 |
| Operations/Maintenance                                   |                        |                   |                   |                   |                      |               |
| Operation                                                | Unit Rates             | Cost Units        | Annual Rates      | Annual Units      |                      |               |
| Building Energy                                          | 0.09 \$/kWh            |                   | 6942 kWh/yr       |                   |                      | \$ 625        |
| Diesel                                                   |                        |                   |                   |                   |                      | \$ -          |
| Labor                                                    | 52 \$/hr               |                   | 1308 hr/yr        |                   |                      | \$ 67,998     |
| Media Replacement                                        | \$ 772,553 \$/unit     |                   | 4 units/ 20 yrs   |                   |                      | \$ 77,255     |
| Natural Gas                                              |                        |                   |                   |                   |                      | \$ -          |
| Process Energy                                           | 0.09 \$/kWh            |                   | 11494 kWh/yr      |                   |                      | \$ 1,034      |
| Subtotal (O&M)                                           |                        |                   |                   |                   |                      | \$ 146,913    |
| Chemicals                                                |                        |                   |                   |                   |                      |               |
| Chemical Name                                            | Chemical Cost          | Cost Units        | Amount            | Consumption Units |                      | Cost          |
| Subtotal (Chemical)                                      |                        |                   |                   |                   |                      | \$ -          |
| Air-Water Backwash System                                |                        |                   |                   |                   |                      |               |
| Process Size                                             |                        |                   |                   |                   |                      |               |
| Base Property                                            | Units                  | Min of Cost Range | Max of Cost Range | Design Cost Basis | Operating Cost Basis |               |
| area                                                     | ft²                    | 0                 | 0                 | 10000             | 10000                |               |
| Construction Costs                                       |                        |                   |                   |                   |                      |               |
| Base Cost                                                | Equipment              | Labor             | Material          | Other             | Subcontract          | Subtotal      |
| Labor                                                    |                        |                   |                   |                   |                      | \$ 81,900     |
| Equipment                                                |                        |                   |                   |                   |                      | \$ 264,000    |
| Pipe & Valves                                            |                        |                   |                   |                   |                      | \$ 313,000    |
| Electrical & Instrumentation                             |                        |                   |                   |                   |                      | \$ 106,000    |
| A. Subtotal                                              |                        |                   |                   |                   |                      | \$ 382,450    |
| Additions/Contingency                                    |                        |                   |                   |                   |                      |               |
| Items                                                    | Formula                |                   |                   |                   |                      | Cost          |
| B. Miscellaneous and Unidentified Site Structures        | (A*0.25)               |                   |                   |                   |                      | \$ 95,613     |
| C. Unit Process Subtotal                                 | (A+B)                  |                   |                   |                   |                      | \$ 478,063    |
| D. Sitework                                              | (C*0.15)               |                   |                   |                   |                      | \$ 71,709     |
| E. Demolition                                            | (C*0)                  |                   |                   |                   |                      | \$ -          |
| F. I&C (SCADA)                                           | (C*0.08)               |                   |                   |                   |                      | \$ 38,245     |
| G. Site Electrical                                       | (C*0.10)               |                   |                   |                   |                      | \$ 47,806     |
| H. Large Piping and Specialty piping                     | (C*0.05)               |                   |                   |                   |                      | \$ 23,903     |
| J. Soil Conditions (Geotechnical requirements)           | (C*0.07)               |                   |                   |                   |                      | \$ 33,464     |
| K. Field General Conditions                              | (C*0.07)               |                   |                   |                   |                      | \$ 33,464     |
| L. Mobilization and Demobilization                       | (C*0.05)               |                   |                   |                   |                      | \$ 23,903     |
| M. Construction Subtotal (excluding miscellaneous items) | (C+D+E+F+G+H+J+K+L)    |                   |                   |                   |                      | \$ 750,558    |
| N. Miscellaneous Elements not Itemized                   | (M*0)                  |                   |                   |                   |                      | \$ 150,112    |
| P. Non-Construction Fees                                 | (P)                    |                   |                   |                   |                      | \$ -          |
| R. Construction Subtotal (including miscellaneous items) | (M+N+P)                |                   |                   |                   |                      | \$ 900,670    |
| S. Sales Tax                                             | (R*0.094)              |                   |                   |                   |                      | \$ 84,663     |

|                                              |                          |                   |                     |                          |  |              |
|----------------------------------------------|--------------------------|-------------------|---------------------|--------------------------|--|--------------|
| T. General Contractor OH and Profit          | $((R+S)*0.15)$           |                   |                     |                          |  | \$ 147,800   |
| U. Bonds and Insurance                       | $((R+S+T)*0.035)$        |                   |                     |                          |  | \$ 39,660    |
| V. Construction Price Today                  | $(R+S+T+U)$              |                   |                     |                          |  | \$ 1,172,792 |
| W. Projection to Mid-point of Construction   | $(V*0)$                  |                   |                     |                          |  | \$ -         |
| X. Market adjustment factor                  | $(V*0)$                  |                   |                     |                          |  | \$ -         |
| Y. Location adjustment factor                | $(V*0)$                  |                   |                     |                          |  | \$ -         |
| Z. Construction Bid Price                    | $(V+W+X+Y)$              |                   |                     |                          |  | \$ 1,172,792 |
| AA. Undesigned Contingency                   | $(Z*0.35)$               |                   |                     |                          |  | \$ 410,477   |
| AB. Construction Budget Price                | $(Z+AA)$                 |                   |                     |                          |  | \$ 1,583,270 |
| AC. Engineering Design Services              | $(AB*0.175)$             |                   |                     |                          |  | \$ 316,654   |
| AD. Engineering Services During Construction | $(AB*0.075)$             |                   |                     |                          |  | \$ 237,490   |
| AE. Construction Administration (CA)         | $(AB*0.04)$              |                   |                     |                          |  | \$ 63,331    |
| AF. Construction Inspection (CI)             | $(AB*0.07)$              |                   |                     |                          |  | \$ 110,829   |
| AG. Legal and Fiscal                         | $(AB*0.05)$              |                   |                     |                          |  | \$ 79,163    |
| AH. Owner Administration                     | $(AB*0.12)$              |                   |                     |                          |  | \$ 189,992   |
| CIP. Total Project Capital Cost              | $(AB+AC+AD+AE+AF+AG+AH)$ |                   |                     |                          |  | \$ 2,580,729 |
| <b>Operations/Maintenance</b>                |                          |                   |                     |                          |  |              |
| <b>Operation</b>                             | <b>Unit Rates</b>        | <b>Cost Units</b> | <b>Annual Rates</b> | <b>Annual Units</b>      |  |              |
| Building Energy                              |                          |                   |                     |                          |  | \$ -         |
| Diesel                                       |                          |                   |                     |                          |  | \$ -         |
| Labor                                        |                          | 52 \$/hr          |                     | 322 hr/yr                |  | \$ 16,745    |
| Materials                                    |                          | 1 \$              |                     | 53 \$/yr                 |  | \$ 10,187    |
| Natural Gas                                  |                          |                   |                     |                          |  | \$ -         |
| Process Energy                               |                          | 0.09 \$/kWh       |                     | 242203 kWh/yr            |  | \$ 21,798    |
| Subtotal (O&M)                               |                          |                   |                     |                          |  | \$ 48,731    |
| <b>Chemicals</b>                             |                          |                   |                     |                          |  |              |
| <b>Chemical Name</b>                         | <b>Chemical Cost</b>     | <b>Cost Units</b> | <b>Amount</b>       | <b>Consumption Units</b> |  | <b>Cost</b>  |
| Subtotal (Chemical)                          |                          |                   |                     |                          |  | \$ -         |