

NDEP Comment (11/16/22)	Response to Comment	NDEP Comment (3/29/23)	Response to Comment
<b>General Comments</b>			
<p><i>General Comment 1: Biological reduction of oxidized pollutants using (potentially renewable) hydrogen offers a sustainable solution to not only the remove, but to destroy these pollutants. A biofilm-based process would be well suited for using a gaseous substrate. Biofilm thickness control is the key challenge with these process units. In this study it appears that biofilm thickness increased until the pressure required in the hydrogen supply increased to above 25 psig, which was considered excessive or unsustainable, despite efforts to use sparging to control film thickness. The undesired sulfate reduction that was observed during the initial phase may also be related to excessive biofilm thickness. In response, it is proposed to clean the membrane every 12 weeks. This introduces several issues, including operating cost, interruption of service and extended startup after resumption of service. Table 10 shows that the cleaning solution and its disposal after use represents more than 27 percent of the operating cost. This does not include the cost of regular interruption to operations. In addition, after cleaning a new biofilm must develop and some of the figures, specifically Figure 7 and 10 or 11, suggest that after cleaning, startup takes up around 50% of the total run time. Regular cleaning would also increase wear on the membranes so that more frequent membrane replacement would be required. The mention in Section 6.4.3 of a new module configuration with improved sparging is of interest and would be key to making the technology viable by allowing continuous operation. This option should be explored further.</i></p>	<p>Comment noted. If a full-scale HBGPM system were considered as part of the final remedy (which will be assessed during the FS), additional testing will be required and many of the points raised in the comment will be taken into consideration at that time. Therefore, no changes to the report have been made in response to this comment, as this comment would likely be addressed during the FS if the HBGPM technology advances through the FS screening process.</p>	<p><i>Indeed, not all challenges can be solved at pilot scale. It might be useful to list the specific challenges remaining to be addressed in future phases, to assist and remind future workers.</i></p>	<p>The following text was added to Section 7:                      “If this technology is considered for full-scale implementation, additional testing and research should be performed to provide data with respect to but not limited to the following:</p> <ul style="list-style-type: none"> <li>• Confirmation that stable and sustainable performance can be achieved (i.e., treatment of perchlorate concentrations at higher mass loading rates to below the 18 µg/L treatment goal);</li> <li>• Evaluation of the optimal ranges of key system parameters including COPC mass loadings, ORP, and consumption rates for hydrogen, carbon dioxide and nutrients; and</li> <li>• Assessment of the most appropriate hydrogen source or generation method, sparging requirements, cleaning procedures, and safety.</li> </ul>
<p><i>General Comment 2: Producing hydrogen on site requires resources, and that very much includes renewable hydrogen. For example, using current technology approximately 60 liters of high-quality water is required per kg of hydrogen produced or about 7 gallons per pound of hydrogen, as mentioned in the comments below. Different methods of hydrogen generation and the economic implications of each method should be considered.</i></p>	<p>As part of the hypothetical full-scale design presented in this report, research was performed to identify technologies capable of generating hydrogen on-site. This resulted in an evaluation of both electrolysis and steam/methane reforming (SMR), both of which are technologies that are rapidly evolving. If the HBGPM technology passes the initial screening completed in the FS, a separate cost-benefit analysis would be required to evaluate the capital and long-term operation and maintenance requirements of an on-site hydrogen generation system as part of the FS. See response to comment <i>Essential Correction 5</i> for further discussion. Since it is more appropriate to evaluate the costs associated with implementing the HBGPM technology during the FS, no changes to the report have been made in response to this comment.</p>	<p><i>NDEP recommends adding a paragraph discussing quantity and quality of feedwater required for on-site hydrogen generation using existing technologies, future improvements notwithstanding. If there is not a nearby source, then this could be a fatal flaw for this technology at this site.</i></p>	<p>While Tetra Tech agrees with this comment, hydrogen technologies are rapidly evolving. While acknowledging that the design of a full-scale system, assuming the technology is selected as part of the NERT final remedy, is at least three years away, NERT believes that expanding on this issue at this time is premature.</p> <p>In acknowledgement of this comment, additional language has been added to Section 6.3.3 indicating the importance of feedwater and how the different methods of hydrogen generation and the economic implications of each method should be evaluated in the Feasibility Study (FS) if the technology advances through the required screening process.</p>

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<p><i>General Comment 3: With regards to the costs developed for the hypothetical design, based on operational cost savings of \$529700-\$185300 = \$344,400 (there may be other savings not listed in this report), a 7 percent discount factor, development costs in year 0 and delivery in years 1 and 2 (with operational savings commencing in year 3). It would take 165 years to “pay off” the \$48M HBGPM facility. However, this does not consider any process augmentations that may be required for the existing FBR system and a complete NPV analysis of these two systems should be undertaken to understand feasibility.</i></p>	<p>As described in Section 1.1 of the report, the primary objective of the Pilot Test was to determine if perchlorate present in extracted groundwater could be effectively treated with the HBGPM technology, with treatment of other contaminants of potential concern, including chlorate and hexavalent chromium, as a potential secondary benefit. The hypothetical full-scale design and preliminary cost estimate presented in this report were prepared since the results of the Pilot Test were favorable. However, as noted in Section 7.0, and discussed in the introduction to this Response to Comments, since the final remedy has not been selected and the design criteria are likely to be substantially refined during the FS process and subsequent Remedial Design if this technology is selected, this cost estimate should not be used for any reason other than recognizing the order of magnitude costs associated with this technology using current groundwater extraction rates and concentrations of contaminants of potential concern (COPCs) and effluent requirements. During the FS, costs related to the various potential components of the NERT final remedy will be presented for relative comparisons with -30/+50 percent accuracy and evaluated consistent with EPA FS guidance inclusive of the non-cost criteria. Therefore, no changes to the report have been made in response to this comment, as this comment would likely be addressed during the FS if the HBGPM technology advances through the FS screening process.</p>	<p><i>Based on information provided it is difficult for the client to make a decision on what groundwater treatment technology is financially beneficial to them. Client should consider undertaking a NPV analysis of the different options before a final remedy is selected.</i></p>	<p>Comment noted. NPV analyses are a documented part of the CERCLA remedy selection process and the NERT is required to adhere to that process.</p>
<b>Essential Corrections</b>			
<p><i>Essential Correction 1: Section Number 2.1 Technology Description Page 2: The chemical reaction equations are not balanced for both FBR and MBfR. Please address and revise as necessary.</i></p>	<p>The coefficients in the chemical equations are not simple theoretical values, but rather complex, empirically determined values which account for biomass generation and consumption. A close review of the literature and discussion with leading researchers in membrane-based biofilm treatment of chlorate and perchlorate has indicated that while the chemical equations are not balanced completely, they are reliable for the purposes of the Pilot Test. The chemical equations included in the report are nearly balanced for the critical constituents; however, in response to the comment, minor coefficient adjustments have been made to more closely balance the equation for all constituents except oxygen. Oxygen is not critical for the assessment or design calculations.</p> <p>The minor edits to the equations were made in Section 2.1 of the revised report.</p>	<p><i>Using hydrogen as a substrate, a balanced equation for nitrate reduction would be:</i>  <math>0.35 \text{ NO}_3^- + \text{H}_2 + 0.33 \text{ H}^+ + 0.05 \text{ CO}_2 \rightarrow</math>  <math>0.01 \text{ C}_5\text{H}_7\text{O}_2\text{N} + 0.17 \text{ N}_2 + 1.13 \text{ H}_2\text{O}</math></p>	<p>The equation has been updated as requested.</p>
<p><i>Essential Correction 2: Section Number 2.1 Technology Description Page 2: Revisit theoretical quantity of ethanol after nitrate equations have been balanced to ensure that quantities are still accurate. Quantities will likely not change as it appears that revising the number of moles of the byproducts produced will balance the equation, however this should be verified.</i></p>	<p>The revised equations for reduction of perchlorate, chlorate, and nitrate indicates that ethanol consumption for perchlorate reduction would be lower by 0.3%, ethanol consumption for chlorate reduction would be lower by 0.8%, and that ethanol consumption for nitrate reduction would not change.</p> <p>The theoretical quantity of ethanol has been updated in Section 2.1 and Section 6.5 of the revised report.</p>	<p><i>To balance the reaction for oxygen and charge, it just needed to be simplified somewhat:</i>  <math>\text{NO}_3^- + 0.707 \text{ C}_2\text{H}_5\text{OH} + \text{H}^+ \rightarrow 0.152 \text{ C}_5\text{H}_7\text{O}_2\text{N} + 0.424 \text{ N}_2 + 2.09 \text{ H}_2\text{O} + 0.656 \text{ CO}_2</math></p>	<p>The equation has been updated as requested.</p>

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<p><i>Essential Correction 3: Section Number 2.1 Technology Description Page 3: Results presented later for both H<sub>2</sub> consumption and biomass production, suggest that the chemical reactions may be underestimating the hydrogen requirement. Please discuss how this can be mitigated.</i></p>	<p>The slight revisions to the HBGPM reaction equations as discussed in responses to Essential Corrections #1 and #2 do not change the HBGPM H<sub>2</sub> and biomass calculations included in the report.</p> <p>Note that excess hydrogen was used during the pilot test. As noted in Section 5.3, no efforts were made to optimize the hydrogen consumption since that was not an objective of the Pilot Test. Therefore, additional optimization testing of a range of hydrogen feed rates is recommended prior to design of a full-scale system if HBGPM technology is selected as part of the NERT final remedy. Therefore, no changes to the report have been made in response to this comment.</p>	<p><i>Some statement should be made in report that this is a reason why the actual hydrogen use was higher than the theoretical calculations. There is no guarantee that 100% efficiency will be achieved in future phases and this should be mentioned.</i></p>	<p>Text has been added to Section 2.3 and Section 5.3:</p> <p>“The amount of hydrogen used during operations was in excess of the theoretical amount of hydrogen required as the purpose of the Pilot Test was to demonstrate, not optimize, the technology. While the study achieved its objectives, it is unknown what efficiencies could be achieved in future iterations of the technology. If this technology were to be deployed by NERT as a component of its final remedy, there are a great number of operational parameters that would be further refined and optimized using the results of this Pilot Test.”</p>																
<p><i>Essential Correction 4: Section Number 2.1 Technology Description Page 3: "Another potential advantage of using hydrogen as the electron donor versus carbon-based electron donor is that the amount of excess biomass generated is theoretically less than that generated when an organic compound (such as ethanol) is used as the electron donor. A system using hydrogen as the electron donor would theoretically generate less waste biomass than a system using ethanol."</i></p> <p><i>Please quantify theoretical solids production for review after rebalancing the chemical reaction equations so that comparisons between to the two donors may be evaluated.</i></p>	<p>The slightly revised chemical reaction equations as discussed in responses to Essential Corrections #1 and #2 did not change the biomass calculation for either a FBR system or a HBGPM system. Therefore, no changes to the report have been made in response to this comment.</p>	<p><i>Solids production should be quantified before full scale implementation. Theoretical savings in solids production per unit mass of pollutant removed.</i></p> <table border="1" data-bbox="1560 745 2318 887"> <thead> <tr> <th></th> <th>FBR</th> <th>HBGPMT</th> <th>Reduction</th> </tr> </thead> <tbody> <tr> <td>CIO<sub>4</sub><sup>-</sup></td> <td>0.682</td> <td>0.125</td> <td>81.7%</td> </tr> <tr> <td>CIO<sub>3</sub><sup>-</sup></td> <td>0.610</td> <td>0.107</td> <td>82.4%</td> </tr> <tr> <td>NO<sub>3</sub><sup>-</sup></td> <td>0.277</td> <td>0.052</td> <td>81.2%</td> </tr> </tbody> </table> <p><i>One might also generalize this information by saving solids production could potentially be reduced by over 80%, at least according to the chemical reactions provided.</i></p>		FBR	HBGPMT	Reduction	CIO <sub>4</sub> <sup>-</sup>	0.682	0.125	81.7%	CIO <sub>3</sub> <sup>-</sup>	0.610	0.107	82.4%	NO <sub>3</sub> <sup>-</sup>	0.277	0.052	81.2%	<p>Comment noted. Solids production will be quantified and evaluated if the technology advances through the required screening steps of the FS. Section 2.1 has been modified to include the bold text below regarding 80 percent reduction.</p> <p>“Another potential advantage of using hydrogen as the electron donor versus carbon-based electron donor is that the amount of excess biomass generated is theoretically less than that generated when an organic compound (such as ethanol) is used as the electron donor. A system using hydrogen as the electron donor would theoretically generate less waste biomass <b>(potentially reduced by more than 80 percent based on the formulas presented herein)</b> compared to a system using ethanol.”</p>
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<p><i>Essential Correction 5: Section Number 2.1 Technology Description Page 3: There are still hurdles to be overcome for hydrogen generation, assuming the hydrogen is generated via electrolysis some challenges include:</i></p> <p><i>1) Water availability/proximity to a water source, feed water quality, brine stream management, and adiabatic cooling requirements which can be a challenge for hot inland areas due to local humidity and ambient temperature conditions.</i></p> <p><i>2) Hydrogen can also be obtained from natural gas reforming, sewage biogas reforming, coal gasification, biomass gasification, etc.</i></p> <p><i>Please discuss the means of obtaining the hydrogen at the site and relative economic implications to assess feasibility.</i></p>	<p>Comment noted. As presented in Section 7 “...if a full-scale HBGPM system were installed, additional testing should be performed prior to final design to fully evaluate the optimal mass loading/mass flux for final design of the required number and configuration of membranes as well as determination of the optimal hydrogen usage. Additionally, research and/or testing would be required to determine the most appropriate hydrogen generation method, nitrogen sparging requirements, and cleaning procedures.” In response to this comment, the following additional text has been added to Section 2.1 of the revised report:</p> <p>“Hydrogen generation technologies are rapidly evolving and the most appropriate means of obtaining the hydrogen at the site and relative economic implications for a full-scale system will be evaluated in the FS or Remedial Design, as appropriate.”</p>	<p><i>Presenting a rough estimate of the resources required for the various options at this point would be beneficial and help the reader understand what a future system may require.</i></p>	<p>Comment noted. Hydrogen generation (including water and hydrogen sources) is a key component that will be evaluated along with various other resources which may be required with respect to implementability of this remedial approach in the forthcoming FS if the technology advances through the required screening steps.</p>																
<p><i>Essential Correction 6: Section Number 2.1 Technology Description Page 3: Hydrogen can be generated in real time and fed directly to the bioreactor only if there is a ready source of fuel i.e., suitable quality water and/or methane/steam. The feasibility assessment in this report assumes supply of hydrogen gas. Please discuss how realistic this is.</i></p>	<p>See response to Essential Correction #5.</p>	<p><i>As above.</i></p>	<p>See response to Essential Correction #5.</p>																

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<p><i>Essential Correction 7: Section Number 2.3 General Operations Page 5: Is it possible to have an online continuous feedback loop as opposed to relying on updating control manually based on system data/perchlorate lab analysis? If the system changes when no monitoring is occurring (i.e., weekend/holiday) what are the risks associated with under/overdosing hydrogen and how should they be controlled? For a full-scale system, the hydrogen generation should be automated so it matches hydrogen consumption in real time.</i></p>	<p>The pilot-scale system was not configured with a feedback loop; however, APTwater has indicated that it continues to work on several system optimization measures. If in the future a full-scale design is warranted, the option of an online continuous feedback loop and need for operator would likely be assessed to ensure hydrogen generation matches consumption to avoid underdosing (system may not meet treatment goals) or overdosing (system inefficiency). Therefore, no changes to the report have been made in response to this comment, as this comment would likely be addressed during the FS if the HBGPM technology advances through the FS screening process.</p>	<p><i>Noted.</i></p>	<p>Response not required.</p>
<p><i>Essential Correction 8: Section Number 2.3 General Operations Page 5: If the process is up-scaled to full-scale installation it is important to also monitor alkalinity which is a buffer to pH. In some biological systems once the pH shifts the biomass is already impacted.</i></p>	<p>Comment noted. Monitoring of alkalinity will be considered in a full-scale design if this technology is selected as part of the final remedy.</p>	<p><i>Noted.</i></p>	<p>Response not required.</p>
<p><i>Essential Correction 9: Section Number 4.2.1 Inspection and Maintenance Page 10: After cleaning is the membrane free of biofilm? Is time needed for re-seeding/acclimatization of biomass following cleaning?</i></p>	<p>In response to this comment, the following bold text was added to Section 4.2.1 of the revised report:</p> <p><b>“The pilot system was shut down for several days in order to complete the cleaning process, which consisted of adding sodium hydroxide to the reactors to raise the pH and remove the biomass from the membranes.”</b></p> <p><b>“After the cleaning process, the membrane was free of biofilm; therefore, reacclimation was required.”</b></p>	<p><i>Refer to comment response in Essential Correction 28.</i></p>	<p>The text has been revised per response to Essential Correction 28.</p>
<p><i>Essential Correction 10: Section Number 4.2.1 Inspection and Maintenance Page 10: Is the whole system offline for several days? If so, the full-scale facility needs to consider redundancy considering these maintenance requirements.</i></p>	<p>In response to this comment, Section 4.2.1 of the revised report has been updated to include the duration when the system was shut down during the cleaning process.</p> <p>The hypothetical full-scale system discussed in Section 6.3.2 included one additional section of modules within each reactor to compensate for the treatment capacity loss during module cleaning. Redundancy for maintenance requirements in a full-scale system will be assessed in the FS, as appropriate.</p>	<p><i>Refer to comment response in Essential Correction 28. Putting a clean module into service next to a 'dirty' one would likely result in more of the gas flowing through the clean membrane (path of least resistance) which would increase hydrogen demand and may require control valving to maintain sufficient gas flow to biofilm containing modules.</i></p>	<p>Comment noted. The text has been revised per response to Essential Correction 28 to indicate that hydrogen control valving would be evaluated in a full-scale design if the technology is selected as part of the remedy following evaluation in the forthcoming FS.</p>

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<p><i>Essential Correction 11: Section Number 5.1.1.1 Test Scenario #1A Page 15: The system appears not to be stable with flow variations, how would a full-scale facility respond to shutdowns?</i></p>	<p>As discussed in Section 5.1.1.1, flow rate changes were prematurely increased during Test Scenario #1A based on operational sample results that were not validated by performance samples, which resulted in the system not meeting the treatment goal at the higher flow rate.</p> <p>For full-scale implementation, the effect of flow variation would be mitigated by including an equalization tank large enough to reduce expected fluctuations in flow. As noted in Section 6.3.1, "In this hypothetical system, extracted groundwater would be directed to an equalization tank to reduce the fluctuations in flow and composition of the influent water. Although the need for an equalization tank would be further assessed during the detailed design process, an equalization tank has been included in the hypothetical design to provide a conservative estimate." Therefore, no changes to the report have been made in response to this comment.</p>	<p><i>A comparison to the equalization requirements for FBR technology might be useful.</i></p>	<p>A comparison to the equalization requirements for the FBR technology is not warranted at this time as flow composition and fluctuations would need to be evaluated and understood once the requirements of the full-scale system are known. During the FS, ex situ treatment technologies will be screened and a comparative analysis will be completed, which will include the concept of equalization requirements.</p>
<p><i>Essential Correction 12: Section Number 5.1.1.1 Test Scenario #1A Page 16: Some discussion is required surrounding the need for thermal insulation in certain applications depending on the site climate and ambient temperature fluctuations. Does thermal insulation need to be included for the NERT facility in the cost feasibility analysis?</i></p>	<p>Section 5.1.1.1 presents a summary of the pilot test system performance, which discusses temperature observations and resulting effects to system operations during the pilot test.</p> <p>With regards to full-scale design and thermal insulation, Section 6.3.8 states the following:</p> <p>"Although temperature control was required during the Pilot Test due to small-scale operations that included storage of water in above-ground holding tanks, temperature control of the equalization tank was not included in the hypothetical full-scale treatment system design since the influent water would be stored in an equalization tank with less than 24 hours of holding capacity. During detailed design of a full-scale system, if such technology was selected as a component of the NERT final remedy, a heat balance would be required to determine if temperature control measures would be required." Therefore, no changes to the report have been made in response to this comment.</p>	<p><i>Given the temperature fluctuations experienced in Nevada, such as the fact that cold dry air could lead to significant cooling in an open EQ tank, and the sensitivity of the system to temperature fluctuations as identified in Section 5.1.1.1 NDEP believes it would be prudent to include in the cost estimate an allowance for thermal lagging of inlet pipe and equalization tank temperature control.</i></p>	<p>Per Section 6.3.8 and original response, temperature control was not included in the hypothetical design due to short holding capacity time. In a full scale implementation, external temperatures will have little impact on the temperature of the influent. It should be noted that a 25% contingency is included in the capital cost estimate for potential components such as temperature control if determined that is required during future evaluations of the technology. During the FS, costs related to the various potential components of the NERT final remedy will be presented for relative comparisons with -30/+50 percent accuracy consistent with EPA FS guidance.</p>
<p><i>Essential Correction 13: Section Number 5.1.1.1 Test Scenario #1A Page 16: The oxygen may inhibit the nitrate/chlorate/perchlorate reactions and increase hydrogen demand. One strategy could be to use air to maintain the ORP at a point where nitrate/chlorate/perchlorate reduction is achieved but before H2S forms. Please discuss whether this strategy could be implemented or whether there is an alternate strategy under consideration.</i></p>	<p>Comment noted. The strategy for full-scale system operation will be further assessed during the FS process, if warranted. Additionally, the bold language has been added to the 3<sup>rd</sup> paragraph in Section 6 of the revised report to address this comment and Comment #27:</p> <p>".. it is noted that very limited testing was performed to optimize system performance, and therefore more tests would be necessary to determine the optimal ranges of key system parameters including COPC mass loadings <b>and ORP</b>, hydrogen, <b>carbon dioxide</b> and nutrient consumption rates, and sparging strategies/frequencies, should HBGPM technology be selected as a component of the NERT final remedy."</p>	<p><i>Noted.</i></p>	<p>Response not required.</p>

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<p><i>Essential Correction 14: Section Number 5.1.1.1 Test Scenario #1A                      Page 16: The PFD does not show the ability to change reactor sequence. This is an important consideration for the full-scale facility. This facility would also allow cleaning one of the reactors while the others remain in service.</i></p>	<p>The ability to change reactor sequence was added to both Figure 2 (pilot treatment system PFD) and Figure 12 (hypothetical full-scale treatment system PFD) of the revised report.</p>	<p><i>Refer to comment response in Essential Correction 28.</i></p>	<p>The following footnote has been added to Figure 12:                       “The hypothetical system includes an additional section of modules within each reactor to compensate for the treatment capacity loss during module cleaning. The remaining sections of modules will continue to treat the influent water while other modules are being cleaned.”</p>
<p><i>Essential Correction 15: Section Number 5.1.1.2 Test Scenario #1B                      Page 16: For full-scale installations is pre-treatment recommended before the membranes? If so, this is currently not shown on the full-scale PFD.</i></p>	<p>Operational data indicated that TSS contained in the influent could adversely impact membrane performance by clogging membrane pores. A pre-treatment filtration system has been added to Figure 12 (hypothetical full-scale treatment system PFD), as well as text in Section 6.3.1 and associated costs presented in Section 6.4 of the revised report.</p> <p>The bold language has been added to the 3<sup>rd</sup> paragraph in Section 6.3.1:                       “In this hypothetical system, extracted groundwater would be <b>directed to a filtration system to remove inert solids that are expected to be in the influent and then to</b> an equalization tank to reduce the fluctuations in flow and composition of the influent water.”</p>	<p><i>Noted.</i></p>	<p>Response not required.</p>
<p><i>Essential Correction 16: Section Number 5.1.1.2 Test Scenario #1B                      Page 17: The variable ORP may indicate sub optimal control of the hydrogen dose. Further investigation into the use of ORP as an online measure is recommended as it could have potential benefits for system control.</i></p>	<p>Comment noted. The strategy for full-scale system operation will be further assessed during the FS process, if warranted.</p> <p>The bold language has been added to the 3<sup>rd</sup> paragraph of Section 6.0 of the revised report to address this comment and Comment #27:                       “.. it is noted that very limited testing was performed to optimize system performance, and therefore more tests would be necessary to determine the optimal ranges of key system parameters including COPC mass loadings <b>and ORP</b>, hydrogen, <b>carbon dioxide</b> and nutrient consumption rates, and sparging strategies/frequencies, should HBGPM technology be selected as a component of the NERT final remedy.</p>	<p><i>Noted.</i></p>	<p>Response not required.</p>

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<p><i>Essential Correction 17: Section Number 5.2.1 Mass Loading Capacity Page 21: Adding the pollutant concentrations is not appropriate, as they would each have different hydrogen demands (i.e., perchlorate is the most difficult to remove) the hydrogen demands for each individual COPC should be added.</i></p>	<p>The pilot test was performed to collect data to inform the key design parameters of mass loading and mass flux rates in the presence of excess hydrogen. The mass loading rate is important as it provides data to indicate the size of the system required to treat a full-scale scenario that involves much larger flow rates than the pilot test. The mass flux rate is the second key design parameter as it is used to determine the total module area and resulting number of modules required per reactor. Although the hydrogen used is critical for biological reduction of contaminants, it is fed into the reactors in excess and therefore, is not appropriate to be used a key design parameter for sizing the hypothetical system. Section 5.3 presents hydrogen consumption calculations, which are based on the hydrogen demands for each individual COPC. As previously noted, optimization was not an objective of this Pilot Test. If this technology is considered for inclusion and further evaluation in the FS, the design basis would be updated with the latest information and technology advancements. Therefore, no changes to the report have been made in response to this comment.</p>	<p><i>The different pollutants each has a different theoretical hydrogen requirement per unit mass of pollutant removed, so simply adding up the mass for all pollutants does not make sense and yields misleading results, since the pollutants cannot be treated as equivalent on a mass basis. To get a meaningful answer for mass loading, it needs to be based on hydrogen consumption, not pollutant load. The data is available to do this and, given that the hydrogen consumption is likely to be optimized in future, would present a conservative (but accurate based on the experimental results) estimate of system capacity.</i></p>	<p>The objective of the pilot test was to demonstrate the efficacy of the technology at remediating perchlorate. Because hydrogen was not optimized in the study, mass loading was the preferred design basis for the hypothetical design. Section 5.2 has been updated to reflect the above rationale for design bases of the study and to reiterate that if the technology is further evaluated in the future, hydrogen optimization testing could be performed. Once that future data is obtained and potential contaminant concentration ranges in the influent are known, a full-scale system design based on hydrogen consumption on a per pollutant basis can be completed.</p>
<p><i>Essential Correction 18: Section Number 5.2.2 Treatment System Flux Page 22: Similar to comment in 5.2.1, hydrogen gas transfer kg H<sub>2</sub>/d/m<sup>2</sup> membrane should be considered. Total mass of COPC is not a valid comparison for scaling up.</i></p>	<p>See response to Essential Correction #17.</p>	<p><i>Our comment stands, as explained for #17 above.</i></p>	<p>See response to #17 above.</p>
<p><i>Essential Correction 19: Section Number 5.3 Hydrogen Consumption Table 4 Page 23: Recommend estimating how much hydrogen is theoretically lost by dissolving in the water. What would be the impact of impurities in the hydrogen feed gas?</i></p>	<p>For all practical purposes, hydrogen is considered to be insoluble in water. At room temperature, hydrogen solubility in water is 0.00016 mole of hydrogen per mole of water. Therefore, hydrogen loss in water is insignificant compared to the loss of hydrogen through escaping the process. As a result, excess hydrogen is used to ensure system performance is not impacted by insufficient hydrogen.</p> <p>Hydrogen impurities in the hydrogen feed gas should be assessed later during a full-scale design if the HBGPM technology is selected as part of the NERT final remedy and once the most appropriate hydrogen generation method is selected. Therefore, no changes to the report have been made in response to this comment.</p>	<p><i>0.00016 moles/mole = 18 mg/L, which is not insignificant compared to other values in Table 4. This demand needs to be included and might explain the bulk of the difference between theoretical and actual dose.</i></p>	<p>The following text has been added to Section 5.3:</p> <p>“However, since hydrogen solubility in water is approximately 18 mg/L, a portion of the excess hydrogen is hydrogen that is lost by dissolving in the water and may represent a significant portion of the difference between the theoretical and actual dose. It is acknowledged that this loss might not be insignificant in the context of a full-scale design and will be further evaluated in the forthcoming FS if the technology advances through the required screening steps.”</p>

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<p><i>Essential Correction 20: Section Number 5.3 Hydrogen Consumption Page 23: Some discussion is required on the possible reasons for the difference between the theoretical/actual dosages and whether this will gap will increase during scaling up. Also per earlier comments the chemical reaction equations were not balanced properly.</i></p>	<p>In response to this comment, the following sentence has been added to Section 5.3 of the revised report:</p> <p>“The actual hydrogen used will always be greater than the theoretical amount as the rate of mass transfer limits the amount of hydrogen that is captured by the biomass before hydrogen is lost to the atmosphere.”</p> <p>It should also be noted as stated in Section 5.3:          “.. no efforts were made to optimize the hydrogen consumption since that was not an objective of the Pilot Test. Therefore, additional optimization testing of a range of hydrogen feed rates is recommended prior to design of a full-scale system if HBGPM technology is selected as part of the NERT final remedy.”</p> <p>See response to comments Essential Comment #1 regarding the chemical equations.</p>	<p><i>It would be useful to clearly point out that the hydrogen dose was in excess and that is probably why actual hydrogen consumption is so much higher than theoretical.</i></p> <p><i>Our response to Correction 17 above also applies: adding up the contaminant mass loading does not yield an accurate theoretical requirement.</i></p>	<p>See responses to #3 and #17 above.</p>
<p><i>Essential Correction 21: Section Number 5.6.1 Biomass Generation Page 26: It's not clear what the units of measurement are (i.e., concentration or mass). Sm needs to be corrected for duration of scenario when solids could accumulate (i.e., in between clean outs).</i></p>	<p>The unit of measurement is milligrams per liter (mg/L), which has been added to the equation in Section 5.6.1 of the revised report.</p> <p><math>S_M</math> (mg/L) represents the quantity of solids accumulated on the membranes from the start of each scenario to the end of each scenario when the membrane was cleaned.</p> <p>The following bold language has been added to Section 5.6.1:</p> <p>“<math>S_M</math> represents the solids accumulated in the membrane <b>from the start of each scenario to the end of the scenario when the membrane was cleaned;</b>”</p> <p>“<math>S_M</math> was calculated using both TOC and TSS results from samples collected during system cleaning at the completion of each scenario <b>and the volume of water that was processed during the scenario.</b>”</p>	<p><i>The mass accumulated would be measured in units of mass (g), not concentration (mg/L). Concentration is used for suspended growth reactors, not biofilm reactors.</i></p> <p><i>It is customary to put units in the description of the symbols in an equation, not in the equation itself.</i></p>	<p>Additional columns have been added to Table 5 to provide the total mass accumulated based on the water used per each test scenario.</p> <p>The equation in Section 5.6.1 was updated so the units are in the description of the equation.</p>
<p><i>Essential Correction 22: Section Number 5.6.1 Biomass Generation Page 26, Table 5: The theoretical biomass should be revised once the chemical reaction equations from Section 2.1 are balanced.</i></p>	<p>See response to Essential Correction #3. The slightly revised chemical equations do not impact the theoretical biomass calculations for the HBGPM system. Therefore, no changes to the report have been made in response to this comment.</p>	<p><i>Noted.</i></p>	<p>Response not required.</p>



NDEP Comment (11/16/22)	Response to Comment	NDEP Comment (3/29/23)	Response to Comment
<p><i>Essential Correction 23: Section Number 5.6.1 Biomass Generation Page 26, Table 5: The pilot system appears to be generating more solids than the theoretical amount. This could explain why the pilot was using more hydrogen than theoretically calculated. Perhaps the theoretical equations don't apply and future scaling up should be based on the measured solids production. Please discuss the approach that will be taken.</i></p>	<p>As shown in Table 5, the actual biomass generated was less than the theoretical values. As noted in Section 5.6.1, "The ratio of actual to theoretical biomass for the pilot test ranged from 0.27 to 0.89 for the various test scenarios, which was expected since the biomass goes through endogenous respiration and gets partially degraded the longer the biomass spends in the reactors. In the APTwater pilot system, since the majority of biomass accumulates on the membrane surfaces, the biomass loss due to endogenous respiration is high." Therefore, no changes to the report have been made in response to this comment, as this comment would likely be addressed during the FS if the HBGPM technology advances through the FS screening process.</p>	<p><i>The fact that the solids yield varied so much and is so different from the theoretical yield highlights the fact that experimental yields should be used in future designs, and the limited utility of the balanced chemical reactions when it comes to solids yield and by extension, theoretical substrate requirements.</i></p>	<p>Comment noted.</p>
<p><i>Essential Correction 24: Section Number 6.1 Design Basis for a Hypothetical Full-Scale HBGPM System Page 29: As discussed in comment on Section 5.2.1, adding the pollutant concentrations is not appropriate, as they would each have different hydrogen demands (i.e., perchlorate is the most difficult to remove) the hydrogen demands for each individual COPC should be added.</i></p>	<p>Please see response to Essential Correction #17.</p>	<p><i>Refer to response in Essential Correction #17 Please add the following column to Table 6.</i></p> <p><i>Theoretical Hydrogen Requirement (lb/day)</i></p> <p style="text-align: center;">70.0 117.9 8.9 196.9</p>	<p>The theoretical hydrogen requirements were added to Table 6. However, as discussed in Section 6.2, the hypothetical system was designed based on mass loading.</p>
<p><i>Essential Correction 25: Section Number 6.2 Reaction Rates for Reduction of Contaminants Page 29: As discussed in comment on Section 5.2.2, hydrogen gas transfer kg H<sub>2</sub>/d/m<sup>2</sup> membrane should be considered. Total mass of COPC is not a valid comparison for scaling up.</i></p>	<p>Please see response to Essential Correction #17.</p>	<p><i>Refer to response in Essential Correction #17 and #24 and please make the necessary correction.</i></p>	<p>Please see response to Essential Correction #17.</p>
<p><i>Essential Correction 26: Section Number 6.3.1 Influent Feed Equalization Tank and Nutrient Delivery System Page 30: The choice of the 25-hour holding time should be explained e.g., is that to hold water during membrane cleaning?</i></p>	<p>Equalization tanks are designed and sized to reduce the fluctuations in flow and composition of the influent water. For biological processes, a 24-hour holding capacity is a conservative rule of thumb. A tank with a 24-hour holding capacity would be approximately 1,440,000 gallons. This total quantity was rounded up to 1.5 million gallons, which equates to approximately 25 hours of holding capacity at the design flow rate. The text in Section 6.3.1 of the revised report was updated for clarity to include the following bold text:</p> <p>"For purposes of design, the equalization tank would be an approximately 1.5-million-gallon carbon steel tank (or equivalent), with the size selected to provide a <b>minimum of 24 hours of holding capacity (a common rule of thumb for sizing equalization tanks)</b> if the system operated at full capacity with a flow rate of 1,000 gpm."</p> <p>As stated in Section 6.3.1, "In this hypothetical system, extracted groundwater would be directed to an equalization tank to reduce the fluctuations in flow and composition of the influent water."</p>	<p><i>NERT should confirm that 24 hours of holding capacity in the equalization tank is sufficient based on current operations experience. A cylindrical steel tank of 1.5 mil gal volume would have dimensions of, for example, 92 ft diameter and 30 ft SWD. An earthen or concrete basin might be more appropriate.</i></p>	<p>Comment noted. Although no report revisions were made as a result of the comment, NERT offers the following response:</p> <p>A 24-hour holding capacity as the basis of design for an equalization tank is appropriate for a conceptual system of this size based on Tetra Tech's professional judgement. Further, it is likely that multiple equalization approaches will be evaluated in the FS if the technology advances through the required screening steps.</p>

NDEP Comment (11/16/22)	Response to Comment	NDEP Comment (3/29/23)	Response to Comment
<p><i>Essential Correction 27: Section Number 6.3.4 Carbon Dioxide Delivery System Page 31: This section states that the hypothetical system would require 11,010 cubic feet of CO<sub>2</sub> per day to buffer elevated pH conditions that would develop during nitrate reduction. CO<sub>2</sub> requirement would be a function of the contaminant removal. Depending on the influent alkalinity, the CO<sub>2</sub> requirement may be met by the influent. Please comment on the possibility of a reduced need for CO<sub>2</sub> by the system depending on alkalinity of the influent.</i></p>	<p>It is possible that the CO<sub>2</sub> requirement may be met by the influent. As noted in Section 6.3.4, the CO<sub>2</sub> requirements for the hypothetical system are based on the pilot test results. However, as noted in the report, additional testing would be required to optimize the system performance.</p> <p>The bold language has been added to the 3<sup>rd</sup> paragraph of Section 6.0 of the revised report to include carbon dioxide as a key system parameter to be optimized:</p> <p>“.. it is noted that very limited testing was performed to optimize system performance, and therefore more tests would be necessary to determine the optimal ranges of key system parameters including COPC mass loadings and ORP, hydrogen, <b>carbon dioxide</b> and nutrient consumption rates, and sparging strategies/frequencies, should HBGPM technology be selected as a component of the NERT final remedy.”</p>	<p><i>Noted.</i></p>	<p>Response not required.</p>
<p><i>Essential Correction 28: Section Number 6.3.7 Maintenance of the Membrane Modules Page 32: More discussion surrounding system sequencing/ bypassing/ redundancy during membrane cleans is required. Will the flow be held upstream during cleaning? Will the reactors be cleaned one by one, and flows bypassed around the reactor being cleaned?</i></p>	<p>The hypothetical full-scale system included one section of modules from each reactor that will be taken offline and cleaned at a time. The remaining sections of modules will continue to treat the influent water.</p> <p>Section 6.3.7 has been updated as follow (addition of bold text):</p> <p>“As described in Section 4.2.1, over time, biomass accumulates over membrane surfaces resulting in a gradual pressure increase in the reactors that can adversely impact membrane performance. APTwater believes that when the pressure reaches a preset value of 25 psi and the system is operated under these conditions for an extended period of time, the structural integrity of the membranes may be compromised. As a result, <b>one section of modules from each reactor</b> of the hypothetical system would be taken out of operation and chemically cleaned once every 12 weeks (based on Pilot Test results indicating a pressure increase to these levels after each 12-week scenario). <b>The hypothetical system includes an additional section of modules within each reactor to compensate for the treatment capacity loss during module cleaning.</b>”</p> <p>Also as noted in Section 6.4.3, APTwater is working on development of modules that do not require chemical cleaning. The number, configuration and cleaning of modules will be reassessed during a full-scale design of the technology if selected as part of the NERT final remedy.</p>	<p><i>Please also add "the remaining sections of modules will continue to treat the influent water." This will clear up a lot of the confusion around redundancy/sequencing of reactors. Also see our comment to essential comment #10.</i></p>	<p>The suggested clarifying text has been added to Section 6.3.7.</p>

NDEP Comment (11/16/22)	Response to Comment	NDEP Comment (3/29/23)	Response to Comment
<p><i>Essential Correction 29: Section Number 6.4.1 Capital Costs Page 33: A contingency of 25 percent was added to the total cost to account for project unknowns during the preliminary stages of the project development; however, this contingency may not fully capture cost escalation associated with the current inflationary environment, supply chain restrictions and other factor associated with the current global economic conditions. It would be beneficial to investigate to identify supply chain issues in more depth in relation to the capital cost of the full-scale facility.</i></p>	<p>As the construction of a full-scale system is likely at least five years out, it would be more appropriate to investigate supply chain considerations at that time.</p> <p>As noted in Section 6.0, “The costs presented should be considered for informational purposes only. During the FS, costs related to the various potential components of the NERT final remedy will be presented for relative comparisons with -30/+50 percent accuracy and evaluated consistent with EPA FS guidance inclusive of the non-cost criteria. The cost evaluation presented herein should not be used to directly compare the treatment costs of a hypothetical system to the current iteration of the on-site GWETS, as such technology comparisons will be accomplished through the NERT FS. Cost comparisons included in this section are strictly hypothetical and made only for the purpose of satisfying the Work Plan objective.” Therefore, no changes to the report have been made in response to this comment.</p>	<p><i>Noted.</i></p>	<p>Response not required.</p>
<p><i>Essential Correction 30: Section Number 6.4.1 Capital Costs Page 33, Table 8: Please include either a hydrogen generator/supply infrastructure or if assuming the gas is delivered then cost a hydrogen storage system.</i></p>	<p>As noted in Section 6.3.3, for purposes of this hypothetical design and cost estimating process, a unit price rate of liquified hydrogen was used. The unit pricing included an onsite hydrogen storage system. Therefore, no changes to the report have been made in response to this comment.</p>	<p><i>It would be good to add a few words to the last sentence of the first paragraph in this section to indicate that onsite storage is included.</i></p>	<p>The bolded text in Section 6.3.3 has been added as follows:          “The current unit price rate of liquified hydrogen <b>with an onsite hydrogen storage system</b> was used in this hypothetical design and cost estimating process.”</p>
<p><i>Essential Correction 31: Section Number 6.4.2 Operating Cost Estimate Page 35: Most of this report has discussed generating hydrogen on-site. Some discussion surrounding the source/availability of the hydrogen gas would be beneficial. Is the intent for the full-scale facility to have green hydrogen? If so approximately 2,400 gallons of suitable quality water would be required per day based on 60L/kg H2 (Naylor, Dagg, Potts, Brannock, Coertzen 2022).</i></p>	<p>Section 6.3.3 provides a brief description of options for generating hydrogen on site. Hydrogen generation technologies are rapidly evolving, and the most appropriate hydrogen generation method should be assessed at the time of full-scale design, if the HBGPM technology is selected as part of the final remedy. Therefore, no changes to the report have been made in response to this comment.</p>	<p><i>Stating approximate quantities, based on current technology would be helpful both as a reminder and to alert future workers to the issue.</i></p>	<p>Comment noted. Although no report revisions were made as a result of the comment, NERT offers the following response:          If this technology passes the initial screening completed in the FS, and becomes a part of final remedy (to which extent is unknown at this time), the quantity of hydrogen needed for a full-scale system would need to be calculated after optimization testing and the requirements for a full-scale system are known.</p>
<p><i>Essential Correction 32: Section Number 6.4.2 Operating Cost Estimate Page 35: Does the carbon dioxide cost include supply to the site? Please provide the quote.</i></p>	<p>The indicative pricing from Air Gas included supply to the site. If this technology is considered for further evaluation during the FS, the operating costs will be updated consistent with -30/+50 percent guidance. Therefore, no changes to the report have been made in response to this comment.</p>	<p><i>Noted.</i></p>	<p>Response not required.</p>
<p><i>Essential Correction 33: Section Number 6.4.2 Operating Cost Estimate Page 36: Annual maintenance based on mechanical and electrical capital costs would be more realistic (as these are the items requiring ongoing maintenance).</i></p>	<p>Estimating maintenance cost at 2% of total capital cost has been used successfully in other project cost estimates by Tetra Tech and is appropriate for the purposes of this hypothetical system budgetary estimate. Therefore, no changes to the report have been made in response to this comment.</p>	<p><i>Noted.</i></p>	<p>Response not required.</p>
<p><i>Essential Correction 34: Section Number 6.4.2 Operating Cost Estimate Page 36, Table 10: This cost assumes 24-hour operation of the centrifuge 365 days per year. Earlier in the report it was stated the centrifuges will operate 4 hours per day. Same comment applies for all other electrical units, are these operating 24 hours per day or intermittently?</i></p>	<p>Table 10 of the revised report has been updated to include operation of the centrifuge for 4 hours per day for consistency within the report.</p>	<p><i>Noted.</i></p>	<p>Response not required.</p>

NDEP Comment (11/16/22)	Response to Comment	NDEP Comment (3/29/23)	Response to Comment
<p><i>Essential Correction 35: Section Number 6.4.2 Operating Cost Estimate Page 36, Table 10: The module replacement cost seems high, what is the anticipated life of the membrane modules? Future optimization efforts should focus on membrane replacement/cleaning (highest cost).</i></p>	<p>The modules are assumed to have a 7-year replacement cycle as footnoted in Table 10.</p> <p>It is noted that optimization of the membrane life cycle and cleaning process is important in a full-scale design. Section 6.4.3 (System Optimization) says “Additional pilot testing would likely result in a more optimized, less expensive full-scale system. Additionally, there are several key system improvements APTwater has identified and is actively pursuing. These improvements include development of modules that do not require chemical cleaning, development of larger modules with more surface area, and reconfiguration of module placement to maximize surface loading.” Therefore, no changes to the report have been made in response to this comment.</p>	<p><i>Noted.</i></p>	<p>Response not required.</p>
<p><i>Essential Correction 36: Section Number 6.4.2 Operating Cost Estimate Page 36, Table 10: The maintenance cost is a fairly significant cost. It might be more accurate to assume a percentage of the mechanical and electrical items which will require maintenance rather than a percentage of the entire capital cost.</i></p>	<p>Please see response to Essential Correction #33.</p>	<p><i>Noted.</i></p>	<p>Response not required.</p>
<p><i>Essential Correction 37: Section Number 6.4.2 Operating Cost Estimate Page 36: Is the solids disposal cost just the gate fee or does it also include the cost of tanks for the liquid waste to the Republic Services Facility?</i></p>	<p>The solids disposal is for the dewatered cake from the centrifuge. The disposal fee was \$46/ton at the time of the report. This unit cost was rounded to \$50/ton to include transport. A more detailed cost estimate (-30/+50 percent) would need to be completed as part of the FS, if warranted. Therefore, no changes to the report have been made in response to this comment.</p>	<p><i>Noted.</i></p>	<p>Response not required.</p>
<p><i>Essential Correction 38: Section Number 6.5 Cost Comparison for Hydrogen vs Ethanol Page 38: Please append the AirGas quote to the report considering it is what is being relied upon for the cost comparison.</i></p>	<p>The costs presented in Section 6.5 are not intended for comparison with the actual operating costs for the existing FBR plant. Should this technology be selected for further evaluation, detailed analyses will be performed in accordance with FS guidance to identify budgetary electron donor costs. Therefore, no changes to the report have been made in response to this comment.</p>	<p><i>In future, NERT should consider this cost in NPV comparison to other alternatives.</i></p>	<p>Comment noted. NPV analyses are a documented part of the CERCLA remedy selection process and the NERT is required to adhere to that process.</p>
<p><i>Essential Correction 39: Section Number 6.5 Cost Comparison for Hydrogen vs Ethanol Page 38, Table 11: A NPV analysis is required to understand if the operational cost savings claimed from H<sub>2</sub>/HBGPM over ethanol/FBR warrant capital investment.</i></p>	<p>As noted in Section 6.5, “<b>Table 11</b> presents a preliminary price comparison based on the hypothetical system developed for costing purposes as required by the Work Plan. These numbers are not intended for comparison with the actual operating costs for the existing FBR plant. Should this technology be selected for further evaluation, detailed analyses will be performed in accordance with FS guidance to identify budgetary electron donor costs.” Therefore, no changes to the report have been made in response to this comment as all relevant Net Present Value analyses will be performed in the FS if the technology is advanced through the FS screening process.</p>	<p><i>In future, NERT should consider NPV comparison to other technology alternatives.</i></p>	<p>Comment noted. NPV analyses are a documented part of the CERCLA remedy selection process and the NERT is required to adhere to that process.</p>

NDEP Comment (11/16/22)	Response to Comment	NDEP Comment (3/29/23)	Response to Comment
<p><i>Essential Correction 40: Section Number 7.0 Summary of Key Findings Page 39: Perchlorate concentrations were not reduced to below the 18 µg/L treatment goal in all scenarios. Scenario 1A did not achieve the target concentration per discussion in 5.1.1.1. The statement that perchlorate concentrations were reduced to below treatment goals in all scenarios should be revised.</i></p>	<p>While the perchlorate effluent concentrations were not consistently below the 18 micrograms per liter (µg/L) treatment goal in Test Scenario #1A, the effluent was below the perchlorate treatment goal in 4 of the 8 weekly performance sampling events (on 9/15/2020, 9/21/2020, 11/6/2020, and 11/19/2020) as shown in Appendix C. Section 5.1.1.1 also states the effluent perchlorate concentrations ranged from 0.39 to 350 µg/L. Therefore, no changes to the report have been made in response to this comment.</p>	<p><i>NDEP still does not agree with this conclusion based on the results shown. NDEP propose: "Perchlorate concentrations were reduced to below the 18 µg/L treatment goal for part of the time in all scenarios."</i></p>	<p>The first bullet in in Section 7.0 has been modified as follows:          "Perchlorate concentrations were reduced to below the 18 µg/L treatment goal in the majority of the samples collected during the performance periods in Test Scenarios #1B, #2 and #3, thus demonstrating that the technology is capable of achieving the goal. Despite the operational issues experienced during Scenario #1A (as described in Section 5.1.1.1), perchlorate concentrations were reduced to below the 18 µg/L in half of the samples collected during the performance period."</p>
<p><i>Essential Correction 41: Figure Number 12: Supporting infrastructure required to generate hydrogen e.g., methane/steam reforming or water electrolysis should be considered and show in this Figure.</i></p>	<p>The supporting infrastructure for the hydrogen generation is dependent upon the final hydrogen generation method chosen. As noted in Section 6.3.3, "If selected as a component of the NERT final remedy, a separate cost-benefit analysis would be required to evaluate the capital and long-term operation and maintenance requirements of an on-site hydrogen generation system. The current unit price rate of liquified hydrogen was used in this hypothetical design and cost estimating process". For the purposes of the hypothetical full-scale system included in this report, the figure includes a third party supplied source of hydrogen. Therefore, no changes to the report have been made in response to this comment</p>	<p><i>Final hydrogen generation technology selected will have significant cost implications and should be flagged in the report as such.</i></p>	<p>The following text has been added to Section 6.3.3 and Section 7.0:          "The hydrogen generation technology will have a significant cost implication for a full-scale system."</p>
<p><i>Essential Correction 42: Figure Number 12: Consider the addition of a cartridge filter upstream of the equalization tank to protect the downstream membranes.</i></p>	<p>Please see response to Essential Correction #15.</p>	<p><i>Noted.</i></p>	<p>Response not required.</p>
<p><i>Essential Correction 43: Figure Number 12: Please show valving/controls to change sequencing of reactors as was necessary during the pilot test.</i></p>	<p>The ability to change reactor sequence was added to Figure 12 – Hypothetical Full-scale Treatment System PFD – of the revised report.</p>	<p><i>For future project phases an operational/control philosophy should be developed so it is clear how sequencing will be completed.</i></p>	<p>Comment noted.</p>
<p><i>Essential Correction 44: Figure Number 12: This bypass would have high COPC concentrations. If the system has the valving to change the lead/mid/lag reactor sequence, The bypass seems unnecessary. Please explain this.</i></p>	<p>Comment noted. Water from the equalization tank would not be used to backwash filters since it has high concentrations of contaminants. Figure 12 – Hypothetical Full-scale Treatment System PFD was revised to remove the line from the equalization tanks to the filter and add a treated water storage tank for filter backwash. A treated water holding tank has been added to text in Section 6.3.6 and associated costs presented in Section 6.4.</p>	<p><i>Noted.</i></p>	<p>Response not required.</p>
<b>Minor Corrections</b>			
<p><i>Minor Correction 1: Section Number 2.1 Technology Description Page 3: Change H<sup>+</sup> to H<sub>2</sub> as H<sub>2</sub> is the reducing agent. Repeat throughout paragraph.</i></p>	<p>Section 2.1 of the revised report has been updated to reference hydrogen gas (H<sub>2</sub>) where appropriate. Note H<sup>+</sup> is still in the equations. H<sup>+</sup> is the hydrogen ion that is present in the water and does not represent hydrogen gas.</p>	<p><i>Noted.</i></p>	<p>Response not required.</p>
<p><i>Minor Correction 2: Section Number 2.1 Technology Description Page 3: It would be easy for the reader if the predicted capacity of the NERT trial and full-scale facility was stated as well as effluent requirements upfront for comparison.</i></p>	<p>Section 2.1 is a description of the general HBGPM. The predicted capacity of a pilot or full-scale was unknown at the start of the pilot test. The effluent requirements are stated in the Section 3.1, Pilot Test Objectives. Therefore, no changes to the report have been made in response to this comment</p>	<p><i>Noted.</i></p>	<p>Response not required.</p>
<p><i>Minor Correction 3: Section Number 5.1.1.2 Test Scenario #1B Page 16: Typo – Achievement is misspelled.</i></p>	<p>Misspelling corrected.</p>	<p><i>Noted.</i></p>	<p>Response not required.</p>