OFFICE OF THE NEVADA ENVIRONMENTAL RESPONSE TRUST TRUSTEE

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September 4, 2020

Dr. Weiquan Dong, P.E.
Bureau of Industrial Site Cleanup
Nevada Division of Environmental Protection
375 E. Warm Springs Road, Suite 200
Las Vegas NV 89119

RE: Seep Well Field Area Bioremediation Treatability Study
Revised 2019 Annual Progress Report
Nevada Environmental Response Trust
Henderson, Nevada

Dear Dr. Dong:

The Nevada Environmental Response Trust (NERT) is pleased to present the revised Seep Well Field Area Bioremediation Treatability Study, 2019 Annual Progress Report for Nevada Division of Environmental Protection (NDEP) review. This report was been revised to address NDEP comments that were provided in your July 9, 2020 letter and includes an annotated response to comments are requested.

If you have any questions or concerns regarding this matter, feel to contact me at (702) 960-4309 or at steve.clough@nert-trust.com.

Office of the Nevada Environmental Response Trust

Stephen R. Clough

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NDEP Comment	Response to Comment
1. The Deliverable does not have fatal flaw.	
2. The EVO Pro mass injected by well has been significantly varying from well to well and specific well from Event 1 to Event 4, which are related to the injection rate and the time duration. What are criteria used to determine how much EVO Pro mass is needed and appropriate for each injection well during each injection event?	The second paragraph in Section 2.1 provides a summary of the overall basis for determining the carbon substrate and distribution water requirements. With regards to quantities on a per well basis, the fourth paragraph in Section 2.1 explains that the quantities of the injectate solution and distribution water varied between injection wells based on the screen lengths and thickness of the targeted formation at each injection location. Because this is a treatability study, the overall injection quantities have been varied among the injection events based on the remediation response observed (perchlorate degradation), TOC concentrations in injection wells during the study (for Injection Event 2 as an example), and also the ability of the injection wells to accept injectate at the maximum pressure permitted during each event. As explained in Section 2.1, "*As part of the injection design process, varying injection quantities were then used during the first three injection events to arrive at an optimal injection quantity. Based on the effectiveness monitoring results, it was determined that the quantities injected during the third injection event, which were approximately 85 percent of the carbon substrate that was injected during the first injection event, resulted in robust perchlorate and chlorate treatment and the sustainment of reducing conditions.*" Once this optimal quantity was determined, the targeted injection quantities for each well during injection events 3, 4 and 5 have remained relatively consistent. Lastly, if an injection well did not accept the targeted injectate volume at the maximum permitted pressure, the carbon substrate solution was redistributed to nearby injection wells as described in Section 2.1 concerning SWFTS-IW13B and SWFTS-IW19.

NDEP Comment	Response to Comment
3. Several downgradient monitoring wells (e.g. SWFTS-MW25, SWFTS-MW23, SWFTS-MW24, SWFTS-MW03, SWFTS-MW09A and PC-94) from the injection wells didn't respond to the Injection Events 2, 3 and 4 as they responded Injection Event 1. Please explain and investigate why perchlorate concentration of these monitoring wells has been staggered after Injection Event 1.	SWFTS-MW23 is not considered hydraulically downgradient, but cross-gradient and therefore, this area would not be expected to be affected by the injections. Based on groundwater flow direction NERT suspects that this area may be impacted by the AMPAC plume which migrates from the west to the east in the vicinity of SWFTS-MW23 (referred to as MW23 in Figure 2 of the revised report) near the Las Vegas Wash. Groundwater samples collected from monitoring well SWFTS-MW24 have observed increases in perchlorate degradation from 68% following the first injection event to 82% following the fifth injection event. Of the remaining four monitoring wells listed in the comment, groundwater samples have indicated some decreases in perchlorate degradation response over time following the subsequent injection events when compared to the response following the first injection event. However, perchlorate concentration reductions in groundwater samples from these wells have still averaged approximately 68 percent, with several sampling events observing up to 89 percent reduction. It may be noted that these monitoring wells are among the farthest downgradient monitoring wells within the treatability study area and are generally located north of a small paleochannel (which was not identified until the final phase of well installation). As a result, this paleochannel is not being targeted by the injected substrate and the proximity of the paleochannel in this vicinity likely contributes to the varying effects on perchlorate concentrations in groundwater samples collected from the downgradient monitoring wells. These wells will continue to be monitored and evaluated to obtain a larger data set that aids the understanding and impacts of the paleochannel over longer periods of time.

NDEP Comment	Response to Comment
4. Specific Comment #1 Section 2.1, Page 3 *How was the amount of distribution water used determined? If the EOS dilution water and the distribution water are added, the percentage of EOS Pro in the water is 5 percent and since EOS Pro is already only 60 percent vegetable oil, this means that the EVO added was fairly dilute.*	As described in the SWF Area Bioremediation Treatability Study Results Report (Tetra Tech, 2019), the quantity of distribution water is equivalent to approximately one pore volume of groundwater and was estimated based on the designed spacing of the injection wells, average depth of the water horizon, and effective porosity in the alluvium in the vicinity in the treatability study area. The EVO was added at a ratio of 1:4 EOS:water followed by the balance of the targeted distribution water. It is correct that the amount of oil itself in EOS Pro is approximately 60 percent emulsified vegetable oil. The dilution recommended by EOS Remediation and in industry-wide protocol documents ranges from 1:4 to 1:20. The follow-up distribution water was injected solely to optimize the distribution of carbon substrate within the vicinity of the injection wells to create a barrier effect to the maximum extent possible and not for dilutional purposes.
5. Specific Comment #2 Section 2.1, Page 3 *Glycerin was added to the injectate solution to serve as an immediate source of carbon to drive the groundwater anaerobic rapidly and reduce acclimation time at the start of the study in first injection but it was not added in the second injection. Glycerin was added at a concentration of about 2 percent of the volume of the EOS Pro in both Injection Events 4 and 5. EOS Pro already contains approximately 4 percent rapidly biodegradable substrate (glycerol according to the SDS) and the groundwater at the site should be close to anaerobic condition; therefore, what is the reason that this small amount of glycerin is added to the mixture?*	Glycerin was not added in the second event based on TOC measurements in the injection wells. However, the degradation response to the second injection event was less than optimal; therefore, glycerin supplementation was resumed thereafter. This is described in more detail in the SWF Area Bioremediation Treatability Study Results Report (Tetra Tech, 2019). Previous EOS products (prior to EOS Pro) had larger percentages of glycerin, closer to 8 percent, as per the EOS vendor and Tetra Tech's prior applications. Glycerin was added at approximately 3 percent by weight of the EOS, which is approximately 4,000 lbs to bring these levels closer to the 6 percent level. Groundwater flow velocities are relatively high in this treatability study area and because of the relatively high nitrate and chlorate concentrations (and thereby flux) in groundwater, a decision was made to add a quick-release substrate (namely glycerin), while hydrolysis of EVO is gradually proceeding to release triglycerides, fatty acids, and finally acetate and hydrogen. The text has been slightly revised in Section 2.1 to elaborate on the purpose of the glycerin in the injectate solution. Additionally, it should be noted that because this is a treatability study, it is important to obtain information on how the aquifer responds to varying injectate solutions and quantities.

NDEP Comment	Response to Comment
6. Specific Comment #3 Section 2.3 *Were there any monitoring parameters that were used to determine when another injection of EVO would take place? What determined the injection frequency shown in Table 1?*	The major trigger for determining the injection timing during this study was the overall increase in perchlorate concentrations, particularly in groundwater samples collected from the nearby wells in between the two transects, which have regularly indicated concentrations less than the laboratory detection limit. In addition, contamination concentration plume maps have been regularly generated to compare plume morphology over time. Because this is a treatability study, groundwater monitoring data will continue to be evaluated to establish a relationship between contaminant concentrations and the requirement for EVO injections, which will provide valuable data for future evaluations of the ISB technology.
7. Specific Comment #4 Section 3.3, Page 9 *Injection wells SWFTS-IW13B and SWFTS-IW19 were the wells that it was not possible to inject into during the fourth injection event, but well SWFTS-IW19 did accept the injection after the well maintenance activities. The analysis of the solids collected from these wells were similar to each other but different from the other wells and presumably is indicative of material that clogs the well rather than just accumulating. What is the explanation for the fact that the well maintenance activities were able to restore function to well SWFTS-IW19 but not SWFTS-IW13B, and what future maintenance could be performed on well SWFTS-IW13B to restore this well?*	A key difference between these two injection wells is length of the injection well screen. Specifically, injection well SWFTS-IW13B has a screen length of 10 feet compared to SWFTS-IW19, which has a screen length of 20 feet. Because SWFTS-IW19 has a longer screened interval, it is open to a larger portion of the aquifer and would be expected to accept higher injection rates. During well maintenance activities at SWFTS-IW19, it was also observed that once the upper portion of the well screen was cleaned of the calcium precipitates, the injection well became increasingly easier to clean with depth, likely due to the presence of more biomass at depth than calcium precipitates. In contrast, the material in the well screen at SWFTS-IW13B appeared to be comprised primarily of calcium precipitates. Additionally, as noted in the footnote in Section 3.4.4.3: *"Subsequent to this reporting period, injection well maintenance was performed in February 2020 on injection well SWFTS-IW13B using the combination of surge and bail, hydrojetting, and chemical addition. This injection well was successfully restored, with post-maintenance water injection testing indicating an injection rate of up to 9 gpm. The results of this maintenance event will be reported in the 2020 Annual Progress Report."* Additional text has been added to Section 3.4.4.3 to provide more details on the variation between injection wells.

NDEP Comment	Response to Comment
8. Specific Comment #5 Section 3.3, Page 9 *Why did the biomass, oleate materials, and calcium salts accumulate in wells SWFTS-IW13B and SWFTS-IW19 only? Is it possible that these wells received less distribution water owing to the positioning of the manifolds, or did groundwater flow cause the injected material to flow in the direction of these wells, or were these two wells overdosed with EVO Pro due to inappropriate mixing during the injection?*	Preferential accumulation of biomass, oleate, and calcium salts is likely due to the heterogeneity in terms of geology, hydrogeology (groundwater flow, velocity, and porosity), and geochemistry at this site. This heterogeneity is evident from the widely differing distribution of gravels, sands, and silts in the subsurface within very short distances laterally and vertically. The presence of a small paleochannel incised into the UMCf in the study area adds further complexity. In addition, there are varying quantities of calcium in the subsurface depending on the mineralogy of the grains and proximity to underlying UMCf. This small- and large-variation would be expected to result in variable deposition of precipitates and biomass in different wells. During injection events, a flow totalizer is installed on each injection well and therefore, the quantity of carbon substrate solution and follow-up distribution water that is injected into each injection well is tracked. As described in Section 2.2: "*In addition to recording injection rates and quantities, the specific gravity of the injectate solution was also periodically measured during the injections to confirm that the solution was being injected as a consistent mixture throughout the injection process.*"
9. Specific Comment #6 Section 3.3, Page 9 *This information is very interesting. A summary table of types of materials accumulating as related to well injection rates and EVO Pro mass could be drawn from this and would be a valuable addition.*	Only four injection wells were sampled for analysis of water and accumulated solids in the injection wells. In general, injection wells with more abundant inorganic precipitates had higher pressure to flow rate ratios during injections (namely, SWFTS-IW-13B and SWFTS-IW19). However, in general, a correlation is not observed between higher total volumes of carbon substrate solution injected during the first five injection events with the presence of more inorganic precipitates. For example, of the three injection wells on which hydrojetting was performed, SWFTS-IW11 had received the most carbon substrate solution to date and also had very minimal amounts of inorganic precipitates. Lastly, of the 14 injection wells that have regularly received 4,000 gallons or more of injectate solution, only five of these injection wells have had well maintenance, all of which were relatively easily to redevelop. In lieu of a table, text has been added to Section 3.3 to provide additional comparisons of material observed in the injection wells to pressure and flow rate.

NDEP Comment	Response to Comment
10. Specific Comment #7 Section 3.4.4 *Some success has been shown in using ethyl lactate to dissolve oleate clogging EVO wells. Will the use of an organic material such as ethyl lactate to dissolve the organic material clogging the well be considered in order to return well SWFTS-IW19 to functionality?*	It is assumed that the comment is referring to returning SWFTS-IW13B to functionality since SWFTS-IW19 successfully received injectate during injection event 5. As previously noted in the report and in response to comment 7 herein, subsequent to this reporting period, injection well maintenance was performed in February 2020 on injection well SWFTS-IW13B using the combination of surge and bail, hydrojetting, and chemical addition. This injection well was successfully restored, with post-maintenance water injection testing indicating an injection rate of up to 9 gpm. The results of this maintenance event will be reported in the 2020 Annual Progress Report. The option of using ethyl lactate for injection wells that accumulate excessive calcium oleate could be considered when other traditionally accepted techniques for well rehabilitation are not effective. Tetra Tech has tested and performed a variety of well cleanup and rehabilitation procedures at NERT. Thus far, the preference is to employ physical mechanisms and, if needed, typical industry-available chemical reagents, generally acids to dissolve precipitated materials, both of which have been successful thus far.
11. Specific Comment #6 Section 4.2.1.1 *Are there any plans to investigate the poor response of well SWFTS-MW15 to the EVO injections or to install another injection well to target this area?*	The option to install an additional injection well to promote a better response of perchlorate degradation in groundwater in the vicinity of SWFTS-MW15 was considered in 2018. However, because this is a treatability study, this modification was deemed not necessary as the study has demonstrated that perchlorate concentrations in groundwater can be reduced to below laboratory detection limits via the injection of a carbon substrate into injection wells and the study is being continued to primarily focus on long-term operation and maintenance. If the technology were implemented in full-scale, additional injection wells would definitely be one option to “fill in the biological” gaps if a similar phenomenon is observed.

NDEP Comment	Response to Comment
12. Specific Comment #7 Section 4.2.1.1 *Does the difference in screened interval between wells PC 91 and PC 92 account for the steady decrease in perchlorate observed at PC 91 as compared to the fluctuations observed at PC 92?*	PC- 91 and PC-92 are slightly downgradient of injection well SWFTS-IW11 but are likely not influenced by injection well SWFTS-IW12 (see Figure 2 of the report). Additionally, the proximity of the paleochannel likely contributes to the varying effects on groundwater perchlorate concentrations in this area. Groundwater flow patterns indicate that groundwater in the vicinity of PC-91 and PC-92 are impacted by injections but the area of PC-91 more so due to its proximity to SWFTS-IW11 and the paleochannel. Lastly, historical perchlorate concentration trends in groundwater collected from both wells were similar through 2015; however, after that (but prior to injections), concentrations in groundwater from PC-91 continued to be similar but groundwater from PC-92 began to indicate higher and less stable concentrations, which is similar to the observations at the nearby upgradient monitoring SWFTS-MW04. It is likely that the same upgradient influence is affecting both SWFTS-MW04 and PC-92, but not PC-91, likely due to the difference in screened interval. Text has been added to Section 4.2.1.1 to provide additional discussion on these two monitoring wells.
13. Specific Comment #8 Section 4.2.3 *As discussed in this section, nitrate removal and perchlorate removal appear to be highly correlated. However, in wells SWFTS-MW19 and SWFTS-MW23, nitrate levels appear to be naturally low (low at baseline event). However, significant perchlorate biodegradation has not been observed in these locations. Has any hypothesis on this been formed?*	SWFTS-MW19 and SWFTS-MW23 are not considered hydraulically downgradient of the injection well transects (See Figure 2 of the report). Specifically, SWFTS-MW23 is cross-gradient and therefore, this area would not be expected to be affected by the injections. Monitoring well SWFTS-MW19 is location on the northern edge of the small paleochannel where flow would be expected to enter the paleochannel from the northwestern portion of the study area and therefore, this area would be less likely to be affected. As a result, fluctuating changes in nitrate and/or perchlorate concentrations are not considered to be treatability study related, but rather natural fluctuations over time.

NDEP Comment	Response to Comment
14. Specific Comment #9 Section 4.2.4 *An increase in total organic carbon (TOC) is typically desired for anaerobic remediation. The United States Environmental Protection Agency (USEPA) (1998) suggests that a TOC greater than 20 milligrams per liter (mg/L) is favorable for anaerobic remediation. This recommendation pertains to chlorinated solvents, and it is true that perchlorate reduction takes place under less reducing condition; however, some increase in TOC may enhance perchlorate remediation. Has any thought been given to increasing the EVO dose to try to increase TOC concentration and to control biofouling in the treatment area?* *The absence of volatile fatty acids in any wells except SWFTS-MW14 and SWFTS-MW16 (low levels) is also an indication of insufficient carbon in the treatment area.*	Typically, for anaerobic groundwater remediation applied through injection well transect systems, it is desirable that organic carbon generally remains within immediate radius of influence of the injection wells and therefore, treats perchlorate contamination in groundwater that migrates through the injection well transect. This is particularly true of slow-release substrates such as EVO that adsorbs or sticks to the soil grains around the injection wells. Therefore, it is not unusual for TOC to be at low levels or absent in groundwater samples collected from monitoring wells located away from the injection well location itself. Please also note the similar response to Comment # 19 as to why it is not desirable or warranted to inject more EVO during each event. Lastly, higher dosages of EVO could inadvertently increase the potential for biofouling. Volatile fatty acids (VFAs) are soluble and very rapidly consumed upon hydrolytic breakdown and anaerobic fermentation of EVO. Its absence or presence at low concentrations is not necessarily an indication of insufficient carbon. Therefore, it is not surprising that low concentrations of VFAs were measured in groundwater even at the nearby wells such as monitoring well SWFTS-MW14 and SWFTS-MW16.

NDEP Comment	Response to Comment
15. Specific Comment #10 Section 4.2.5 *The lack of sustained reductions in oxidation reduction potential (ORP) and increases in methane and ferrous iron suggest that long lasting anaerobic conditions have not been established other than in wells MW 14 and MW 16. This is another indication that an increased EVO dose may be warranted. Has any thought been given to increasing the EVO dose to try to enhance and sustain anaerobic conditions in the treatment area?*	As part of the treatability study process, the original intent and premise has and continues to be the creation of sufficiently reducing conditions closer to the injection points without promoting reducing conditions downgradient of the injection well transects. Establishing reducing conditions within the immediate radius of influence of the injection wells will treat perchlorate contamination in groundwater as it migrates through the transect rather than create very strongly reducing conditions that could be problematic and detrimental for reasons stated below. As stated in Section 4.2.5.4, *"Methanogenic conditions (signified by biological methane production) require highly reducing conditions that are generally not warranted for perchlorate biodegradation."* Highly reducing conditions that would result in increases in methane would also likely result in extensive biological sulfate reduction given that this aquifer contains an average sulfate concentration of 2,000 mg/L. As explained in Section 6.2.6.3, "*Sulfate biodegradation is not desirable for various reasons, primarily that it results in: (i) unnecessary consumption of carbon substrate; (ii) overproduction of sulfate-reducing microorganisms that could overtake perchlorate-reducing microorganisms; (iii) the formation of hydrogen sulfide; and (iv) loss of hydraulic permeability.*" Based on the above reasoning, it is the opinion of Tetra Tech that increasing the EVO quantities may be detrimental in this groundwater setting.
16. Specific Comment #11 Section 4.2.6 *The sentence "The Bio Trap® collected from downgradient well SWFTS-MW09B had the highest proportion of General (Nsats) at 62.22 percent during the reporting period" should be edited to explain that Nsats are normal saturated fatty acids that are found in all organisms, and, therefore, the prevalence of these types of fatty acids and absence of other fatty acids that may indicate more diverse organisms indicates that the bacteria population may be less diverse in this area.*	Text in Section 4.2.6 has been edited to describe the Nsats in more detail.

NDEP Comment	Response to Comment
17. Specific Comment #12, Section 4.2.6 *This section discusses the higher concentration of eukaryotes in the sample from well SWFTS MW14 and states that this is sometimes an indication of inefficient destruction of contaminants but that this is not the case at well SWFTS-MW14 as good removal of perchlorate has been observed at this well. What then, if anything, is the significance of the relatively high population of eukaryotes in this well?*	Text from Section 4.2.6 states the following: *"The emergence of low percentages of Eukaryotes is sometimes an indirect indication of **efficient** destruction of the prime contaminants. It may be noted that groundwater from SWFTS-MW14 has historically responded the most rapidly and favorably to the injection of the carbon substrate throughout the study period."* It should be noted that the statement in Section 4.2.6 uses the word "efficient" and not "inefficient" as the comment indicates. Therefore, the emergence of the Eukaryotes in the biotrap® collected from this well correlates with the significant perchlorate removal observed in groundwater samples collected from SWFTS-MW14.
18. Specific Comment #13, Section 4.2.6 *Was any consideration given to trying a biotrap "baited" with perchlorate in well SWFTS-MW14 or SWFTS-MW16 to learn more about the population which is degrading the perchlorate? It seems unlikely that this population was captured on the biotraps given the low perchlorate concentration at SWFTS-MW14 at the time when the biotraps were deployed and the lack of perchlorate biodegradation in the other biotrap wells.*	Perchlorate reducing microorganisms (PRMs) have been previously identified in groundwater from this area during UNLV bench-scale studies and in bio-traps® installed during previous post-injection sampling events as described in the SWF Area Bioremediation Treatability Study Results Report (Tetra Tech, 2019). Therefore, the installation of baited bio-traps® was not deemed necessary.
19. Specific Comment #14, Section 5.2 *The cost effectiveness of the injection of less substrate is discussed; however, the injection of a higher concentration of substrate at a lower frequency may achieve greater cost savings and enhance the biodegradation of perchlorate.*	Both lowered quantities of substrate and lowered frequency of injection (greater timeframes between injection events) are being evaluated as part of this extended treatability study. Adding higher quantities of substrate as suggested could actually be problematic at this site as discussed in previous responses. Specifically, past UNLV bench-scale column studies performed using soil and groundwater from area treatability studies showed that higher quantities did not result in greater longevity under these high groundwater flow conditions. Secondly, given the high amounts of sulfate in this aquifer, higher substrate concentrations could also result in unwanted secondary impacts such as increased sulfate reduction, excessive biomass growth, and precipitation.
20. Reference USEPA. 1998. Technical Protocol for Evaluating Natural Attenuation of Chlorinated Solvents in Groundwater. Cincinnati, OH: National Risk Management Research Laboratory, Office of Research and Development, USEPA. EPA/600/R 98/128	Noted.