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PILOT STUDY UIC CLASS V WELL

2020

From:	Combs, Robert
To:	Cobrain, Dave, NMENV; Suzuki, Michiya, NMENV
Cc:	Tsinnajinnie, Leona, NMENV; VanHorn, Kristen, NMENV; Chavez, Carl J, EMNRD; Griswold, Jim, EMNRD; Holder, Mike; Leik, Jason; Speer, Julie (JSpeer@trccompanies.com); Todd, Levi; Smith, Catriona V. (CVSmith@trccompanies.com); Denton, Scott
Subject:	[EXT] re: HWB-NRC-19-002
Date:	Friday, May 29, 2020 1:36:00 PM
Attachments:	2020-05-29 Pilot Test WP Appr wMods RTC combined.pdf

Dave and Michiya,

Please find the attached response letter to the April 6, 2020 Approval with Modifications for our Revised Groundwater and Phase-Separated Hydrocarbon Recovery System Enhancements: Reinjection Pilot Test Work Plan. Two hardcopies with electronic files are being submitted to NMED and one hardcopy to OCD via FedEx. The electronic file will be uploaded to OCD on Monday (6/1/20).

If you have any questions or would like to discuss, please let us know.

Thanks and have a good weekend!

Robert

HOLLYFRONTIER®

May 29, 2020

Mr. Kevin Pierard, Chief
Hazardous Waste Bureau
New Mexico Environment Department
2905 Rodeo Park Drive East, Building 1
Santa Fe, New Mexico 87505

Re: Response to April 6, 2020, Approval with Modifications Letter, *Revised Groundwater and Phase-Separated Hydrocarbon Recovery System Enhancements: Reinjection Pilot Test Work Plan*, December 2019
HollyFrontier Navajo Refining LLC, Artesia Refinery
EPA ID No. NMD048918817
HWB-NRC-19-002

Dear Mr. Pierard:

HollyFrontier Navajo Refining LLC (HFNR) appreciates the New Mexico Environment Department's (NMEDs) April 06, 2020, Approval with Modifications Letter (Approval Letter) regarding the December 2019 *Revised Groundwater and Phase-Separated Hydrocarbon Recovery System Enhancements: Reinjection Pilot Test Work Plan* (Work Plan).

The Approval Letter provided comments on the Work Plan, several of which pertained to the requirement that the Pilot Test demonstrate reduction of hydrocarbons to below standards in a single, one pore-volume, pass. This requirement suggests that additional discussion of how the proposed recovery system upgrades will be used to contain and treat groundwater could benefit the understanding of the intent of the full-scale system, Pilot Test, and Work Plan. As discussed in a meeting with NMED and New Mexico Oil Conservation Division (OCD) staff in March 2018, proposed full-scale operation consists of two separate injection and recovery systems that will prevent impacted groundwater from under the Refinery proper from migrating to the agricultural field to the east. As discussed in more detail in the responses below, one injection and recovery system will operate below the Refinery and the second under the agricultural field between the Refinery eastern fence line and Bolton road. Each system is completely separate and has individual product recovery, groundwater amendment, injection, and recovery components. Groundwater withdrawn from the recovery systems will have any free product removed, be amended to facilitate in-situ biodegradation, and be reinjected at the upgradient boundary of its respective system. By operating as a continuous recovery and injection system, multiple pore volumes will be injected to flush product and degrade hydrocarbons in the groundwater. The multiple pore-volumes anticipated with the pilot study are consistent with the multiple pass full-scale recovery system upgrades. Based on the dual system approach, removal of hydrocarbons to risk-based levels in a single pore-volume is not necessary. The results of the proposed pilot study, including the collection of additional subsurface hydrogeologic data, will be used to update the full-scale hydrogeologic model and provide the basis for the design of the full-scale recovery system upgrades.

This letter provides responses to the NMED's Approval Letter dated April 06, 2020, regarding the Work Plan and includes replacement pages corresponding to the revisions discussed below. NMED indicated that no response was required on several comments; however, HFNR provides the following responses to all of NMED's comments (shown in *italics*) in an effort to facilitate mutual understanding of the Work Plan. HFNR looks forward to working with NMED on the remaining considerations on the Work Plan, and looking to the future, the pilot study.

RESPONSE TO NMED COMMENTS

Comment 1

The Permittee is reminded that NMED has expressed concerns about the effectiveness of the in situ bioremediation method chosen to conduct the Pilot Test. Nevertheless, the Pilot Test should allow for a clear demonstration of the adequacy of the remedy that will be utilized to design the full-scale system should the Pilot Test be successful.

Response 1

The proposed full-scale groundwater recovery/injection system will be set up with two separate closed loops – one loop under the Refinery and a second loop under the field east of the Refinery and operated simultaneously (see Attachment 1). Because of the recovery along the eastern Refinery boundary, and the reinjection of recovered water from along Bolton road, a hydraulic barrier is created along the Refinery fence. The system will be designed so that water from under the Refinery is recycled several times through the Refinery loop and not allowed to pass into the east field where it could migrate to Bolton Road. The recovery-injection loop under the east field will require multiple pore volume exchanges, as phase-separated hydrocarbons (PSH) will have to be desorbed from the soil matrix and be broken down via enhanced natural attenuation. Since additional hydrocarbon impacts from beneath the Refinery will be cut off by the hydraulic barrier, treatment of the groundwater in the field east of the Refinery will be facilitated. The information gathered during the Pilot Test will be used to determine the efficacy of the full-scale system as a remedial alternative and provide the basis for its design and operation.

Comment 2

The Permittee's response to NMED's Disapproval Comment 1, page 3, paragraph 1 states that "[t]he water that is reinjected will have a similar concentration of dissolved hydrocarbons as the groundwater extracted from the formation. Any reduction in dissolved hydrocarbon concentrations can only be attributable to additional in situ degradation due to increased SRB activity as confirmed by the sampling program proposed in the Work Plan." There is currently no data to support this statement. Since groundwater is extracted and reinjected, fluid movement within the aquifer matrix will change, which can cause the adsorbed contaminants to be released, mobilized, diluted, and volatilized in the vicinity of the injection and extraction wells. The aboveground operations associated with processing groundwater and mixing the amendments may cause volatilization of constituents. Furthermore, recirculation will not be a completely closed system; injection fluid will flow outside of the network and fresh groundwater will flow into the network from outside of the test cell. Unless additional data (e.g., carbon isotope analysis) is collected to support the accuracy of the statement, the Permittee cannot assume that all observed reductions in dissolved hydrocarbon concentrations is only attributable to microbial activity enhanced by the amendments. No response required.

Response 2

As described in Response 1, multiple pore-volume exchanges are planned with the pilot study; consistent with the plans for the full-scale system. The selection of the type of pilot study – enhanced biodegradation by sulfate-reducing bacteria (SRB) – is based on evidence that this process is currently occurring. Historic monitoring data indicate that lower concentrations of sulfate occur in areas with historical hydrocarbon impacts as shown in Attachment 2.

One of the objectives of the Pilot Test is to evaluate whether the apparent existing process can be enhanced to facilitate degradation of hydrocarbons in the subsurface. Multiple lines of evidence will be used in the evaluation of the pilot study results to determine potential contributing factors to reductions in concentrations that may be observed. These multiple lines of evidence (see Section 5.5 of the Work Plan) include the following:

1. Constituents of Concern (COC) concentration data in upgradient, pilot study, and downgradient monitoring wells, and the influent and effluent of the treatment cell.
    a. COC concentration trends:

i. Concentrations will typically increase for a short period (1 to 3 months) as a result of increased microbial mediated desorption rates.
ii. As the microbial community acclimates and grows, degradation rates will meet and exceed desorption rates, resulting in decreasing hydrocarbon concentration trends.
iii. The desorption/degradation process is key to the *in situ* biodegradation process; microbes tend to degrade adsorbed organics at a faster rate than soluble organics, resulting in the potential short-term increase in dissolved phase hydrocarbons followed by decreasing concentrations.
iv. Desorption and degradation of the adsorbed phase minimizes or eliminates dissolved phase rebound.

b. Relative concentration changes in the dissolved phase constituents: Evidence of enhanced biodegradation will be differential degradation rates for various aromatic compounds (e.g., ethylbenzene may degrade faster than xylenes, benzene may degrade faster than ethylbenzene, etc.).

2. Influent COC concentrations, and influent and effluent concentrations of sulfate, TKN and field parameters at the amendment and reinjection system.
3. Sulfate and nutrient demand and concentration data.
4. Subsurface redox conditions and other MNA parameter values.
5. Correlations between MNA and hydrocarbon concentration data.
6. Pump and injection tests are planned to be conducted prior to injection of amendment at each pilot study location. The data collected from these tests and groundwater elevations measured during the pilot study will be used to evaluate the subsurface hydrogeologic conditions that will be used in the interpretation of the pilot study results.

Comment 3

The Permittee's response to NMED's Disapproval Comment 1, page 3, paragraph 2 states, "[i]f the recirculated water is treated ex-situ as suggested, it will not be compatible with the anaerobic degradation approach and, in addition, the aerated water would swiftly foul injection wells and the formation without further chemical amendment." Unless the data to evaluate the severity of fouling due to the precipitation of minerals in groundwater is provided, the viability of an aboveground groundwater treatment system must not be excluded from future consideration. Additionally, biofouling of injection wells is also likely to occur under anaerobic conditions by enhanced microbial activity. The issue associated with the precipitation of minerals may be easier to resolve in comparison to that of biofouling. No response required.

Response 3

Iron fouling is a major issue when oxygen-rich water (e.g., air stripper effluent) is recharged through injection wells or during air sparging when oxygen is injected into an anaerobic environment. Enhanced anaerobic biodegradation systems are designed to reduce/eliminate the introduction of oxygen in any portion of the recirculation system. Anaerobic fouling is generally much slower than iron fouling and can be managed on an annual or biannual basis vs. the far more frequent effort necessary to control iron fouling issues associated with the introduction of oxygen into a dissolved iron-rich water-bearing zone environment.

Slow rates of injection well fouling have been observed during some sulfate recirculation systems. Injection rates, injection pressures, and groundwater elevations will be used during the pilot study to evaluate whether fouling may be occurring. If observed to occur, it will be managed on a periodic basis, just as it would for a full-scale system.

Comment 4

The Permittee's response to NMED's Disapproval Comment 4, page 4, paragraph 1 states, "[b]ased on the data, HFNR does not believe that the MTBE detected in RA-4798 can be conclusively attributed to historic refinery operations. No other dissolved volatile organic compounds (VOCs) have been detected in groundwater samples collected from RA-4798. Because MTBE is more recalcitrant and mobile than VOCs, there are numerous potential sources of MTBE upgradient of RA-4798 in addition to the Refinery that may be the source of detected concentrations." NMED does not agree with the statement that MTBE "detections cannot be attributed to historical Refinery operation based on all available data." The Permittee has not demonstrated that historical operations did not contribute to the MTBE detections or provide other possible sources for MTBE in the September 2019 Evaluation of Methyl Tert-Butyl Ether (MTBE) in Groundwater (September 2019 MTBE Report). The Permittee is not required to submit a response at this time. The comment can be addressed after the Permittee receives NMED's comments from the September 2019 MTBE Report.

Response 4

MTBE will be addressed separately from the Pilot Test and after receiving NMED's comments on the September 2019 MTBE Report.

Comment 5

The Permittee's response to NMED's Disapproval Comment 5.a. pages 5 through 6 discusses changes made to the proposed Pilot Test locations. The Permittee proposed two locations, one *near RW-19 and the other at MW-131. In the response to comments letter and the revised Work Plan, the Permittee discusses how the locations will be verified as proper locations for the Pilot Test; however, the Permittee does not discuss what will happen if either location is not appropriate. During initial discussions and meetings, the Permittee also proposed another location for the Pilot Test which was west of MW-99 and north of RW-15. The location between MW-99 and RW-15 must be reserved as a contingency in case one of the two locations are not usable for the Pilot Test.*

Response 5

Alternate locations were provided in Appendix A of the December 2019 Revised Pilot Test Work Plan: one location west of MW-99 and one location south of MW-105. These locations are reserved as alternate locations in the Work Plan. Should one of the primary locations prove inappropriate, then HFNR will notify NMED of the conclusion, identify one of the proposed alternate locations, and obtain NMED acceptance of the alternate location prior to proceeding with the Pilot Test (see also Response 12).

Comment 6

The Permittee's response to NMED's Disapproval Comment 5.a., page 6, paragraph 2 states that "[t]arget concentrations for the full-scale system will be based on the results of the Pilot Test but are expected to be similar to the initial target concentration of the Pilot Test. The actual amount of sulfate amendment in the full-scale system will also be adjusted based on actual conditions observed during operation of the system. The remedial timeframe may vary as it will be proportional to the mass of hydrocarbons in the targeted zone." The groundwater must meet the permit clean up standard prior to reaching Bolton Road. However, if all hydrocarbon constituent concentrations in groundwater cannot be reduced below the applicable standards while applying one pore volume of the amended groundwater during the Pilot Test, the demonstration will be considered as ineffective for full-scale implementation. Therefore, if multiple pore volumes need to be exchanged in order to reduce the concentrations below the applicable standards during the Pilot Test, the results cannot be directly interpreted to design the full-scale system. Furthermore, in order to demonstrate the comparability, the injection rate during the Pilot Test is suggested to be decreased to a lower rate than proposed to simulate the reaction time anticipated for the full-scale operations. In addition, the initial dose of amendments must be enough to satisfy the target concentrations in the formation to stimulate the SRB population and maintain microbial activity throughout operation of the full-scale system. No revision or response required.

Response 6

The proposed full-scale dual loop groundwater recovery/injection system will involve multiple pore volume exchanges to reduce hydrocarbon concentrations as described in Response 1. Therefore, the need to limit the pilot study to one pore volume is not required in order to show that the demonstration can be effective for full-scale implementation.

The plan for multiple pore volume exchanges during the pilot study is consistent with the proposed full-scale system and will allow a better prediction of the performance of the full-scale system. The proposed pilot study with multiple pore volume exchanges is intended to provide information that can be used to design the full-scale system.

With multiple pore volume exchanges for both the full-scale system and the pilot study, the injection rate does not need to be adjusted to achieve comparable reaction times. As described more fully in Response 21, the injection rate will be based on the aquifer pump and step-injection test results.

In a recirculation cell system with multiple pore volume exchanges, *in situ* sulfate demand is met with amendment of sulfate to the extracted groundwater prior to reinjection back into the subsurface. This approach eliminates the need to provide all of the sulfate amendment in one dose to meet the total demand and also allows adjustment of the sulfate amendment to match the demand throughout the duration of the recirculation.

Comment 7

The Permittee's response to NMED's Disapproval Comment 6, page 8 states "[as] described in this section of the Work Plan, an initial evaluation is to be performed prior to installation of Pilot Test wells (discussed further in Comment 7) to confirm (1) the presence of gravel through gamma logging and potentially exploratory borings and (2) confirm or adjust the location/design of the Pilot Test wells based on the results." Exploratory borings must be included to confirm the lithology in the area. The Permittee cannot rely on gamma logging alone, especially since there are electrical and water lines near the Pilot Test locations.

Response 7

It is HFNR's intent to conduct the Pilot Test in both gravels and silty sand subsurface geologic conditions that have been observed at the Site. HFNR wants to ensure that the pilot study is meaningful and that predictions stemming from the pilot study for the full-scale system are as accurate as possible to ensure a successful full-scale system.

The approach to the issue of whether the target geology in a particular location is appropriate has always been a multi-step process:

- First, and significantly, HFNR plans to conduct the pilot study in two locations to ensure that the pilot study is being conducted in areas with "representative" conditions.
- Second, the geology from available wells in the vicinity of these locations was a primary factor in selecting the locations for study.
- Third, gamma logging is planned to be conducted to confirm that the resulting logs are consistent with the described geological descriptions.
- Last, there are multiple wells to be installed at each Pilot Test location from which additional borehole (BH) geologic information will be observed/recorded and can be used to confirm the appropriateness of the location. Specifically, the gamma logs will be confirmed by the BH data for the pilot wells. The BH data will also be used to ensure that the gamma logs were not affected by subsurface utilities. Should BH data indicate that a location is not appropriate, additional work will be performed to locate a suitable alternative.

As discussed in the Work Plan and in Response 5, should one of the primary locations prove inappropriate, HFNR will notify NMED of the conclusion, identify one of the proposed alternate locations, and obtain NMED acceptance of the alternate location prior to proceeding with the Pilot Test.

Comment 8

The Permittee's response to NMED's Disapproval Comment 7, page 8 states "[i]f the evaluation directs the placement to be different from the chosen areas, these will be noted as deviations in the Pilot Test report." NMED must also be notified, if a location is not acceptable and must be relocated.

Response 8

HFNR will notify NMED if either of the two primary locations is not appropriate. Should one of the primary locations prove inappropriate, then HFNR will notify NMED of the conclusion, identify one of the proposed alternate locations, and obtain NMED acceptance of the alternate location prior to proceeding with the Pilot Test (see also Response 5).

Comment 9

The Permittee's response to NMED's Disapproval Comment 13.b., page 15 states "HFNR proposes moving the Pilot Test location near KWB-5 to near RW-19, and as such removing MW-

99 from the proposed baseline groundwater monitoring program." MW-99 must remain a part of the baseline groundwater monitoring program for the reasons listed in the Permittee's response to Comment 13.b. It is important to monitor groundwater migrating from the Facility. MW-66 must also be included in the baseline groundwater monitoring program.

Response 9

The Work Plan will be updated to include MW-66 and MW-99 in the baseline groundwater monitoring program for the pilot program. Following the pilot program, and if the dual-loop full-scale system is installed, HFNR will revisit the need for continued monitoring of MW-99.

Comment 10

The Permittee's response to NMED's Disapproval Comment 13.c., page 15 states, "HFNR will install one additional upgradient monitoring well closer to the Pilot Test area near MW-131 (PMW-6) after completion of the baseline evaluation." According to Figure 2b (Proposed Recovery, Injection, and Monitoring Locations near MW-131), the location of proposed. upgradient well PMW-6 is shown approximately 160 feet upgradient of well lW-2. The location of proposed well PMW-6 is too far from well IW-2 to observe any potential influence. The proposed well PWM-6 must be installed 100 feet or less upgradient of well IW-2 to better evaluate the effects of the injection well. Revise the applicable sections of the report and provide replacement pages and figures, as necessary.

Response 10

The location will be situated within 100 feet or less of IW-2. The revised location will be reflected in a replacement page for the Work Plan once and based on the presence of utilities/infrastructure, Refinery operational constraints, and NMED's suggestion regarding proximity to IW-2.

Comment 11

The Permittee's response to NMED's Disapproval Comment 13.e, page 15 states, "[t]he objective of the Pilot Test is to demonstrate sulfate-facilitated degradation of hydrocarbons, regardless of the source of the sulfate." Sulfate levels in the vicinity of the extraction wells for the full-scale system (i.e., Bolton Road) are relatively high. If the extracted groundwater contains sulfate levels above 500 mg/L, the proposed addition of sulfate from Epsom salt may not be necessary. No revision or response required.

Response 11

HFNR acknowledges the comment and appreciates the consideration for the full-scale system. As described also in response to NMED's Disapproval Comment 13.e, page 15, sulfate amendment rates will be adjusted during the Pilot Test based on groundwater sulfate demand monitoring results as described in response to NMED's Disapproval Comment 5b. As mentioned in the prior response, the source of the sulfate is not critical and the target sulfate concentration in the subsurface during the pilot study is 500 to 1,000 mg/L. It is more important during the pilot study to evaluate whether anaerobic degradation with sulfate is feasible rather than evaluating whether 500 mg/L may be sufficient. These parameters will be tracked and included in the report. If the Pilot Test is effective, then the sulfate demand and target concentration of sulfate for the full-scale system will be evaluated at that time.

Comment 12

The Permittee's response to NMED's Disapproval Comment 15, page 17, paragraph 2 states that the Permittee does not agree with NMED's requirement that additional borings must be completed to provide additional support to the gamma-log study to verify the gravel seam and silty sand presence. The Permittee references geologic data in the East Field, testing for the Contaminant Migration Evaluation (CME) Report, and the boring logs as being enough information to rely on the gamma-log study. However, the Permittee states that they will consult with NMED to determine the number and location(s) of any additional soil borings after reviewing the results of the gamma logging evaluation. The results from the revised CME Report are still under review. However, based on the Permittee's conclusions, the data cannot easily be correlated to the specific lithology of the site. In the response letter, explain if the gamma-log study has similar limitations. Soil borings will be required to verify the gamma-log study.

Response 12

It is HFNR's intent is to conduct the Pilot Test in the gravel and silty sand subsurface geologic conditions that have been observed at the Site. HFNR wants to ensure that the pilot study is meaningful and that predictions stemming from the pilot study are as accurate as possible in order to ensure a successful full-scale system.

There are current BH logs from wells in the vicinity of each Pilot Test location and, therefore, it is not a situation where information is unavailable. The gamma logging is intended to provide additional and complimentary information to these current BH logs. There are no limitations to completing the gamma logging at this site because the gamma signature of silty sand and gravel are completely different. The gravel lens will be obvious and can be correlated to the existing boring logs. The approach to the issue of whether the target geology in a particular location is appropriate has always been a multi-step process:

- First, and significantly, HFNR plans to conduct the pilot study in two locations to ensure that the pilot study is being conducted in an area with “representative” conditions.
- Second, the geology from available wells in the vicinity of these locations was a primary factor selecting the locations.
- Third, gamma logging is planned to be conducted to evaluate whether the resulting logs are consistent with the described geological descriptions (split spoon recovery rates were low in the suspected gravel seam which can be a typical sampling result in gravel or running sand; the gamma logs will verify the thickness of the permeable formation) or whether there are inconsistences or anomalies between the data sets. Injection and extraction wells will be designed based on the gamma logging results.
- Last, there are multiple wells to be installed at each Pilot Test location from which additional BH geologic information will be observed/recorded and can be used to confirm the appropriateness of the location. Specifically, the gamma logs will be confirmed by the BH data for the pilot wells. Should BH data indicate that a location is not appropriate, additional work will be performed to locate a suitable alternative.

As discussed in the Work Plan and in Response 5, should one of the primary locations prove inappropriate, HFNR will notify NMED of the conclusion, identify one of the proposed alternate locations, and obtain NMED acceptance of the alternate location prior to proceeding with the Pilot Test.

Comment 13

The Permittee's response to NMED's Disapproval Comment 17, page 18 states, "[t]hese recovery wells have three separate well casings installed within the larger 14-inch diameter outer casing. One casing is used for groundwater recovery (4-inch diameter casing), one for PSH recovery (4- inch diameter casing), and one for instrumentation (1-inch diameter casing). The groundwater recovery pump intake will be set below the water table surface and operated to prevent intake of PSH." Accordingly, two submersible pumps are installed at different depths to extract PSH and groundwater separately. PSH will likely accumulate at the groundwater interface induced by the recovery pumps. In the response letter, explain how to ensure that the inlet of the PSH recovery pump is positioned at the interface while the inlet of the groundwater recovery pump is positioned below the PSH/groundwater interface.

Response 13

The PSH pump is a pneumatically-operated pump that floats at the oil-water interface. These pumps are designed to recover free product at the interface. The groundwater submersible pump will be set at a depth below the drawdown predicted at the selected extraction rate based on the pump test. Because these two pumps are not in the same well casing, the pumps, hoses, and control wires/tubing will not interfere with one another. Their location in different well casings has no bearing on the levels of groundwater and PSH in either the water-bearing zone or the well casings. Groundwater levels will be measured during the Pilot Test to ensure that the pumps remain at appropriate depths throughout the pilot study.

Appendix B in the Work Plan shows the pumps, their relative depths, and the well casings. Attachment 3 shows the groundwater and PSH recovery schematic that depicts how the PSH recovery pump and groundwater recovery pumps will be positioned relative to fluid levels.

Comment 14

The Permittee's response to NMED's Disapproval Comment 24, page 23 states, "[t]he pump intake depth must remain below the water surface so that air is not entrained during extraction and to prevent pump malfunction." Some pumps (e.g., pneumatic and liquid ring pumps) allow fluid recovery at the interface; therefore, the PSH recovery pump must be capable of handling dual phase fluids. No revision or response required.

Response 14

NMED's Disapproval Comment 24 pertained to Section 5.2.7, Groundwater Monitoring, in the April 2019 Work Plan. The discussion in this section pertained to setting the low-flow sampling pump intake during groundwater monitoring, not the depth of the recovery pump. However, in HFNR's revision, the discussion regarding the depth of the recovery pump was added to this section in response to Comment 24. This discussion is better placed elsewhere to avoid confusion between the sampling pump intake, the recovery pump intake, and the PSH recovery pump intake.

The *groundwater sampling pump intake* will be set approximately 2 feet below the groundwater drawdown elevation to avoid sampling colloids. The *groundwater recovery pump intak*e will be set below the groundwater table at a depth appropriate to the recovery zone of interest and the expected drawdown and will be operated in a manner such that the groundwater drawdown will not exceed 2 feet below the lowest groundwater elevations as provided in the Work Plan. The groundwater elevation will be monitored during the pilot study to adhere to this constraint. The *PSH floating skimmer pump* is designed to pump PSHs. It is undesirable to pump both PSH and water, or PSH and air, as this is not efficient and is indicative that the pump is not floating at the right level or working properly. In this application, dual-phase pumps are not appropriate. Please see the fluid recovery schematic referenced in Response 13 (Attachment 3).

The Work Plan will be revised to clarify the depths of the groundwater sampling pump intake (Section 5.2.7) and the groundwater recovery pump intake (Section 5.2.2).

Comment 15

The Permittee's response to NMED's Disapproval Comment 26, page 24 states, "[a]s described in Response 25, this target concentration [500 mg/L] was selected based on the HFNR team's experience with similar projects but will be adjusted based on estimated sulfate demand within each Pilot Test area." Since PSH is present and the PSH desorption is necessary to attenuate the PSH plume, the target concentration may need to be increased to remediate dissolved-phase constituent to concentrations below the applicable standards while applying one pore volume of the injection fluid. The Permittee must not apply more than one pore volume of the· injection fluid during the Pilot Test to demonstrate the applicability for the full-scale system. No response required. (see also Comment 6).

Response 15

The Pilot Test and anticipated full-scale system include recovery of both PSH and groundwater. The sulfate demand and target concentration is based on addressing the dissolved PSH, which includes desorbed PSH.

The full-scale groundwater recovery/injection system will be set up with two separate closed loops – one loop under the Refinery and a second loop under the field east of the Refinery and operated simultaneously. Because of the recovery along the eastern Refinery boundary, and the reinjection of recovered water from along Bolton road, a hydrologic barrier is created along the Refinery fence. The system will be designed so that water from under the Refinery is recycled several times through the Refinery loop and not allowed to pass into the east field where it could migrate to Bolton Road. The recovery-injection loop under the east field will require multiple pore volume exchanges, as PSH will have to be desorbed from the soil matrix and be broken down via enhanced natural attenuation. Since additional hydrocarbon impacts from beneath the Refinery will be cut off by the hydraulic barrier, treatment of the groundwater in the field east of the Refinery will be facilitated.

The sulfate concentrations will be monitored at the beginning to achieve sulfate target concentrations at or above 500 mg/L. On-going sulfate addition in the injection fluid is anticipated in order to maintain sulfate target concentrations in the water-bearing zone (between approximately 500 and 1,000 mg/L) for suppling the sulfate demand created by desorbed PSH.

Comment 16

The Permittee's response to NMED's Disapproval Comment 36, page 28, paragraph 2 states, "if the trend in concentration data is decreasing and indicates target concentrations in groundwater could be reached in a reasonable period of time beyond the timeframe of the Pilot Test, this data can still be used in design of upgrades to the full-scale system. In other words, failure to reach any predicted percent reduction may not result in the approach being deemed unsuccessful." Even if the constituent concentrations trends continue to decrease during the Pilot Test, the decline may or may not be sustained after the Pilot Test has been completed. The initial decline of constituent concentrations associated with an increased activity of sulfate reducing bacteria (SRB) may often plateau over time. Therefore, it may be difficult to fully determine if the effectiveness of the remedial design is demonstrated during the timeframe of the Pilot Test. No revision required.

Response 16

Multiple lines of evidence will be used in the evaluation of the pilot study results. These multiple lines of evidence (see Section 5.5 of the Work Plan) include the following:

1. COC concentration data in upgradient, pilot study, and downgradient monitoring wells, and the influent and effluent of the treatment cell.
    a. COC concentration trends:
        i. Concentrations will typically increase for a short period (1 to 3 months) as a result of increased microbial mediated desorption rates
        ii. As the microbial community acclimates and grows, degradation rates will meet and exceed desorption rates, resulting in decreasing hydrocarbon concentration trends
        iii. The desorption/degradation process is key to the *in situ* biodegradation process; microbes tend to degrade adsorbed organics at a faster rate than soluble organics, resulting in the potential short-term increase in dissolved phase hydrocarbons followed by decreasing concentrations.
        iv. Desorption and degradation of the adsorbed phase minimizes or eliminates dissolved phase rebound.
    b. Relative concentration changes in the dissolved phase constituents: Evidence of enhanced biodegradation will be differential degradation rates for various aromatic compounds (e.g., ethylbenzene may degrade faster than xylenes, benzene may degrade faster than ethylbenzene and xylenes, etc.).
2. Influent and effluent COC concentrations, sulfate, TKN, and field parameters at the amendment and reinjection system.

3. Sulfate and nutrient demand and concentration data.
4. Subsurface redox conditions and other MNA parameters.
5. Correlations between MNA data and hydrocarbon concentration data.

Asymptotic concentration trends may occur in water-bearing zones with residual smear zones that are periodically above the water table. This situation will need to be managed and accounted for in the full-scale design. We have seen at other sites that remedial action objectives can be achieved in reasonable time frames with the proposed Pilot Test approach without stalling at asymptotic levels; the Pilot Test trends will provide sufficient information to estimate the remedial timeframe.

Comment 17

The Permittee's response to NMED's Disapproval Comment 39, page 30, paragraph 1 states that "sulfate injected during the Pilot Test or the full-scale system will be used by the indigenous SRB to consume hydrocarbons, or if not used, captured by the downgradient recovery system and sent back "upstream". Once the goals of the system are achieved, the sulfate injections will stop, and aquifer conditions will return to aerobic conditions." It is anticipated that the injection fluid will not be completely captured by the downgradient recovery system; some amended sulfate will migrate outside of the network and will not be recovered by the injection wells. Furthermore, the aquifer at the locations affected by hydrocarbons is anaerobic and ceasing the sulfate injections would not change the aquifer's aerobic or anaerobic state. In the response letter, explain why and how the cessation of the sulfate injections "will return the aquifer to aerobic conditions".

Response 17

The water-bearing zone is currently anaerobic near the Pilot Test areas, likely due to natural degradation of the dissolved hydrocarbons. After the cessation of amendment, the water-bearing zone will likely take many years to reach aerobic conditions due to the level of non-hydrocarbon-based TOC in the formation (bacteria byproducts, tannins, humic acids, etc.). The estimated time to return to aerobic conditions is difficult to predict as it depends on many factors (including rate of recharge by aerobic recharge water, degree of mixing with soil atmosphere as a result of fluctuating groundwater elevations, and oxygen demand by the microbial community as the non-hydrocarbon [microbes, tannins, etc.] carbons are oxidized).

To clarify, HFNR's statement was that "…aquifer conditions will return to aerobic conditions." This statement does not indicate a direct causality between the cessation of sulfate injection and return to aerobic conditions. The statement is intended to convey that the removal of PSH, residual, and dissolved phase hydrocarbons via sulfate amendment and reinjection until dissolved concentrations are below applicable standards, allow the water-bearing zone to eventually return to aerobic conditions due to the naturally-occurring processes listed in the paragraph above after treatment is completed.

To the point that, "some amended sulfate will migrate outside of the network and will not be recovered by the injection wells," (it is assumed NMED meant some amended sulfate will migrate outside of the network and will not be recovered by the *recovery* wells) sulfate concentrations ranging from 1,500 to 3,000 mg/L or greater have been measured north, west, south, and east of the Refinery well outside of the area impacted by hydrocarbon releases (see the sulfate figure provided in Attachment 2). NMED's Comment 11 of this current response points out that naturally-occurring sulfate concentrations outside of the impacted areas are equal to or greater than the proposed target sulfate concentration for the Pilot Test. Sulfate amended groundwater in the range of 500 to 1,000 mg/L, as proposed for the Pilot Test, would not have any foreseeable impact in terms of sulfate concentrations on the surrounding water-bearing zone. In addition, during the Pilot Test, the current recovery systems will remain in use, including the system along Bolton Road.

Comment 18

The Permittee's response to NMED's Disapproval Comment 39, page 30, paragraph 2 states, "[f]ree hydrogen sulfide gas is persistent in acidic environments or in environments absent of metals to precipitate the sulfide. Groundwater in the Shallow Saturated Zone across the refinery contains dissolved metals (including iron) and is neutral as indicated by pH data collected in the field during routine semi-annual groundwater events, thus, sulfide end products will primarily be precipitated." Both acid producing bacteria and sulfate reducing bacteria thrive under reductive and nutrient-rich environments. Acidification of groundwater is often observed in the aquifer where hydrocarbon degradation is prominent. An elevated sulfide level is often observed in the aquifer where hydrocarbon degradation is occurring; however, acidification of groundwater may further dissolve metals possibly causing sulfide not to precipitate. In order to support the Permittee's statement, include qualitative acid producing bacteria analysis (e.g., BART Hach Tests) as an additional qualitative monitoring parameter. If the Permittee decides to include additional qualitative acid producing bacteria analysis, discuss the sampling frequency in the response letter and include a table summarizing the data similar to the one required for the SRB results in Comment 20.

Response 18

An end-product of hydrocarbon degradation under sulfate-reducing conditions is bicarbonate, a buffer. The field parameters include pH, which will provide an indication of the acidification of groundwater.

Nonetheless, HFNR will conduct limited qualitative acid-producing bacteria analysis (e.g., BART Hach Tests) as an additional qualitative monitoring parameter. We will conduct BART Hach Test analyses for acid producing bacteria in the upgradient monitoring wells, proximal downgradient monitoring wells, and the existing and proposed new monitoring wells within each Pilot Test area prior to the start of the pilot study, quarterly, and at the end of the pilot study. A table summarizing the results will be provided in the Pilot Study Report.

Comment 19

In Section 5.2.5 (Treatment Efficiency Evaluation), page 25, paragraph 3, the Permittee states that "[m]agnesium and conductivity will also be used as tracers throughout the Pilot Test." The Permittee must collect baseline measurements for magnesium migration across the Refinery fence line, in the Pilot Test area and downgradient of the Pilot Test area prior to starting the Pilot Test.

Response 19

Magnesium is currently identified in the Work Plan as an analyte that will be monitored as part of the baseline groundwater quality evaluation (Section 5.2.1) and as part of groundwater monitoring (Section 5.2.7). With the addition of MW-66 and MW-99 to both the baseline and groundwater monitoring programs, magnesium data will be collected "across the Refinery fence line." If dissolved magnesium is partially stable in the water-bearing zone, magnesium concentrations can be used to estimate sulfate demand during the initial phase of the project. As bicarbonate concentrations increase, magnesium solubility will decrease, and it will no longer be a reliable tracer.

Comment 20

In Section 5.2.7 (Groundwater Monitoring), page 27, paragraph 3, bullet item 3, the Permittee lists SRBs as a qualitative measurement during the Pilot Test. The Permittee did not discuss the sampling frequency for the SRBs in the revised Work Plan. Discuss the sampling frequency for the SRB qualitative measurements in the response letter. In the Pilot Test report, provide a table summarizing the SRB qualitative data to include the sample location (e.g., monitoring well, injection well, or recovery well), date sampled, time of sample (e.g., baseline, first injection, second injection, etc.), observations from samples and results, and date ofresult reading.

Response 20

HFNR will conduct limited qualitative sulfate-reducing bacteria analysis (e.g., BART Hach Tests) as a qualitative monitoring parameter. We will conduct BART Hach Test analyses for sulfate-reducing bacteria in the upgradient monitoring wells, proximal downgradient monitoring wells, and the existing and proposed new monitoring wells within each Pilot Test area prior at the start of the pilot study, quarterly, and at the end of the pilot study. A table summarizing the results will be provided in the Pilot Study Report.

Comment 21

In Section 5.5 (Treatment Test Effectiveness), page 36, bullet item 3, the Permittee states that a "[n]umber of estimated pore volume exchange cycles completed within the Pilot Test area compared to the predicted number of pore volume exchange cycles for the Pilot Test operating parameters (e.g., injection and recovery rates) and observed conditions. Based on the expected range of Pilot Test operating parameters, the predicted minimum and maximum number of pore volume exchanges within each Pilot Test area over the 18-month Pilot Test are estimated to be 1.5 (injection/pumping rate of 1 gpm) and 17.5 (injection/pumping rate of 12 gpm)." In order to meet the one pore volume requirement (see Comments 6 and 15) over the 18-month Pilot Test period, the injection rate must be adjusted based on one pore volume of the estimated Pilot Test boundary. Furthermore, injecting water at a higher rate may risk physically removing (flushing) the adsorbed material, which is less likely to occur during the full-scale operation. The results from the Pilot Test would provide positively biased data for the design of the full-scale system if physical removal of hydrocarbons predominantly occurs during the Pilot Test. This may provide misleading results about the effectiveness of the in situ EAB. Revise the statement and provide replacement pages, where applicable.

Response 21

The complete groundwater recovery/injection system will be set up with two separate closed loops – one loop under the Refinery and a second loop under the field east of the Refinery and operated simultaneously. Because of the recovery along the eastern Refinery boundary, and the reinjection of recovered water from along Bolton Road, a hydrologic barrier is created along the Refinery fence. The system will be designed so that water from under the Refinery is recycled several times through the Refinery loop and not allowed to pass into the east field where it could migrate to Bolton Road. The recovery-injection loop under the east field will require multiple pore volume exchanges, as PSH will have to be desorbed from the soil matrix and be broken down via enhanced natural attenuation. Since additional hydrocarbon impacts from beneath the Refinery will be cut off by the hydraulic barrier, treatment of the groundwater in the field east of the Refinery will be facilitated.

Accordingly, since multiple pore volume exchanges are anticipated, the injection rate will be based on the pump and step-injection test results and will be selected so that it is representative of the injection rates for the full-scale system. HFNR will provide this proposed flow rate to NMED after the initial pump testing is completed to ensure OCD, NMED, and HFNR are in agreement on the flow rates for the test before testing with amendments begins. Because the pilot study is not restricted to one pore volume, the injection rate does not need to be increased above what is otherwise needed, and flushing during the pilot study is expected to be similar to the proposed system upgrade.

Comment 22

In Section 5.5 (Treatment Test Effectiveness), page 36, bullet item 3, the Permittee states, "[t]his estimate assumes the following for each Pilot Test area: effective area of approximately 12,000 square feet {60 feet by 200 feet), effective saturated thickness of 20 feet, and saturated porosity of 30%." According to Appendix B (Proposed Well Construction Diagrams), the screened interval of the injection wells is proposed to be 10 feet. The effective saturated thickness within the Pilot Test boundary must be assumed to be equivalent to the length of the injection well screen {10 feet). Correct the pore volume calculation accordingly and provide replacement pages. Additionally, the effective area is assumed to be a 60-foot by 200-foot rectangle. The assumption appears to be overly simplified. The Permittee has previously provided a flow simulation model to predict flow paths for the injection fluid. It is advisable to use the same flow simulation model to predict the size of the effective area for the Pilot Test. Furthermore, a saturated porosity of 30% used for the calculation was not provided with a reference. An actual effective porosity must be used for the calculation. If the porosity value (30%) was a site-specific parameter previously determined, provide a reference in the response letter; otherwise, a site-specific value must be obtained.

Response 22

Pore volume will be calculated based on an effective saturated thickness of 10 feet. In addition, given that both the Pilot Test and the full system have been designed to ensure multiple pore volume exchanges, the need to precisely calculate and predict a single pore volume more accurately with modeling than what has already been provided does not appear to be warranted.

The spacing of the proposed injection, monitoring, and recovery wells for the Pilot Test was designed based on known hydraulic conductivity values for the areas where the Pilot Test will be performed. Radius of influence of recovery and injection based on known hydraulic conductivity were used to ensure injection and recovery wells were far enough apart to not overlap (creating a preferential loop and biasing the test), but close enough to ensure that the injected fluid would migrate following natural potentiometric gradients into the capture zone of the recovery well. -The model was set up and calibrated for the area encompassed by the full system. Application of the model to the smaller specific pilot study areas could require additional data collection and calibration to have confidence in the results, which again does not appear to be warranted given that the number of pore volumes is only being used for qualitative purposes.

The flow paths from the injection well to the extraction well will be contained within an ellipsoid which is approximated by the rectangle. The number of pore volume exchanges will simply be used qualitatively to confirm that they were sufficient for distribution of amendment and, in conjunction with other monitoring parameters, to confirm the creation of a subsurface anaerobic sulfate-reducing environment. Since the actual pore volume will be smaller than what is calculated using the geometric assumption in the revised work plan, our approach is conservative and ensures that we will get multiple pore volume exchanges to simulate how the full-scale system will operate.

It should be noted that the results of the Pilot Test, including the results from injection and pump testing done before the reinjection testing starts, will be used to update and validate the model for the full-scale system before the final full-scale system is implemented.

The Work Plan (Section 5.2.8) identifies specific yield (effective porosity) as a parameter that will be determined from the pump testing at each of the pilot study areas. This resultant site-specific effective porosity will be used to estimate the actual number of pore volume exchanges that occurred during the Pilot Test.

Comment 23

In Section 6.0 (Schedule), page 38, bullet item 7, the Permittee describes the tables that will be a part of the deliverables for the Pilot Test report. The Permittee must also include a table of parameters used to help determine the final results of the report. The table must include units and must include the reference from previous investigation reports or studies if they are not from data collected during the investigation. The Permittee must also include a discussion about the table of parameters and provide an explanation for the values used.

Response 23

A table of parameters used to help evaluate the results of the pilot study will be included in the pilot study report. The table will include units and references from previous investigation reports or studies for values that are not derived from data collected during the investigation. The table below provides an example of the parameters that will be used to evaluate the pilot study results; however, other parameters may also be used as determined during the pilot study.

Table of Parameters on which to Evaluate the Pilot Study Results (Preliminary)

Parameter	Units	Use
Concentration of COCs[1] in upgradient wells	ug/L,	Changes in concentration unrelated to the pilot study
Concentration of COCs[1] in pilot study monitoring wells	ug/L	Concentration trends; Relative concentration changes between COCs between compounds with variable degradation rates
Concentrations of COCs[1] in downgradient wells	ug/L	Change in concentration potentially related and potentially unrelated to pilot study
Influent COC[1] concentrations	ug/L	Concentration trends
Concentration of sulfate in upgradient wells	ug/L	Changes in concentration unrelated to the pilot study
Concentration of sulfate in pilot study monitoring wells	ug/L	Estimate sulfate demand; adjust sulfate amendment
Concentration of sulfate in downgradient wells	ug/L	Change in concentration potentially related and potentially unrelated to pilot study
Influent and effluent concentrations of sulfate, TKN	ug/L	Estimate sulfate and nutrient demand; used to adjust amendment
Other MNA laboratory-measured parameters – TOC, alkalinity, ferrous iron, sulfide, magnesium	mg/L or ug/L	Assess redox conditions and effect of redox conditions on water-bearing zone.
MNA Field parameters at each well: DO, ORP, pH, temperature, conductivity	DO – mg/L; ORP – millivolts; pH – S.U.; temperature – ^{o}F; conductivity – Siemens/meter	Assess redox conditions in water-bearing zone; assess degree of acidity. pH used to assess risk of creating conditions of increasing dissolved metal concentrations
Acid-generating bacteria (BART Hach Test Kit)	Qualitative indication of cfu/mL (Very High to Low)	Assess potential risk of affecting pH
Sulfate-reducing bacteria	Qualitative indication	Used to qualitatively assess potential

Parameter	Units	Use
(BART Hach Test Kit)	of cfu/ML (Aggressive to Non -aggressive)	presence of SRB (Note that "Non-Aggressive" can be a false negative because of the nature of the sample)
Number of Pore Volumes	Number	Qualitative assessment of distribution of amendment – used in conjunction with sulfate and TKN analyses
Depth and thickness of free product – extraction well and each monitoring well	Ft	Ensure that skimmer pumps are set at proper depth and operating correctly
Groundwater elevations – each well	Ft amsl	Groundwater flow direction, groundwater drawdown, groundwater capture, potential groundwater excursions
Groundwater elevations, injection rate, and pressure at injection well	Ft amsl, gpm, psi	Used to assess correct injection and monitor for potential fouling
Volume of PSH recovered	Gallons	Document recovery volume
Specific capacity	Ft^2/day	Water-bearing zone hydrogeological characteristic
Vertical hydraulic conductivity	Ft/day	Water-bearing zone hydrogeological characteristic
Horizontal hydraulic conductivity	Ft/day	Water-bearing zone hydrogeological characteristic
Transmissivity	Ft^2/day	Water-bearing zone hydrogeological characteristic
Coefficient of storage	Unitless	Water-bearing zone hydrogeological characteristic
Specific yield	Unitless	Water-bearing zone hydrogeological characteristic

[1] Constituents of Concern (COCs): benzene, toluene, ethylbenzene, xylene (BTEX), 1,2,4-trimethylbenzene (TMB), 1,3,5-TMB, methyl tert-butyl ether (MTBE), naphthalene, gasoline range organics (GRO), and diesel range organics (DRO).

CLOSING

HFNR has included replacement pages for the Work Plan corresponding to the revisions discussed above (see Attachment 4). HFNR would appreciate the opportunity to discuss the above comments and responses with the NMED prior to implementing the Work Plan to ensure all parties are in agreement on the proposed approach. Please let us know a convenient time for discussion following your review. HFNR is prepared to implement the Work Plan within 90 days of concurrence on the items above, COVID-19 restrictions allowing. Should you have any questions or need any additional information prior to our discussion of the above responses, please do not hesitate to contact me by phone at (575) 746-5487 or Robert Combs at (575) 746-5382.

Sincerely,

Scott M. Denton
Environmental Manager

Attachments:
Attachment 1. Dual Loop Modeled Full-Scale Recovery System
Attachment 2. Depressed Sulfate Concentrations within the Dissolved Hydrocarbon Plume
Attachment 3. Dual (separate) Phase Groundwater and Phase-Separated Hydrocarbon Recovery Schematic
Attachment 4: Replacement Pages for the *Revised Groundwater and Phase-Separated Hydrocarbon Recovery System Enhancements: Reinjection Pilot Test Work Plan*, December 2019

cc: NMED: D. Cobrain, K. Van Horn, L. Tsinnajinnie, M. Suzuki,
OCD: C. Chavez, J. Griswold
HollyFrontier: M. Holder, R. Combs, J. Leik
TRC: J. Speer, L. Todd, C. Smith

ATTACHMENT 1

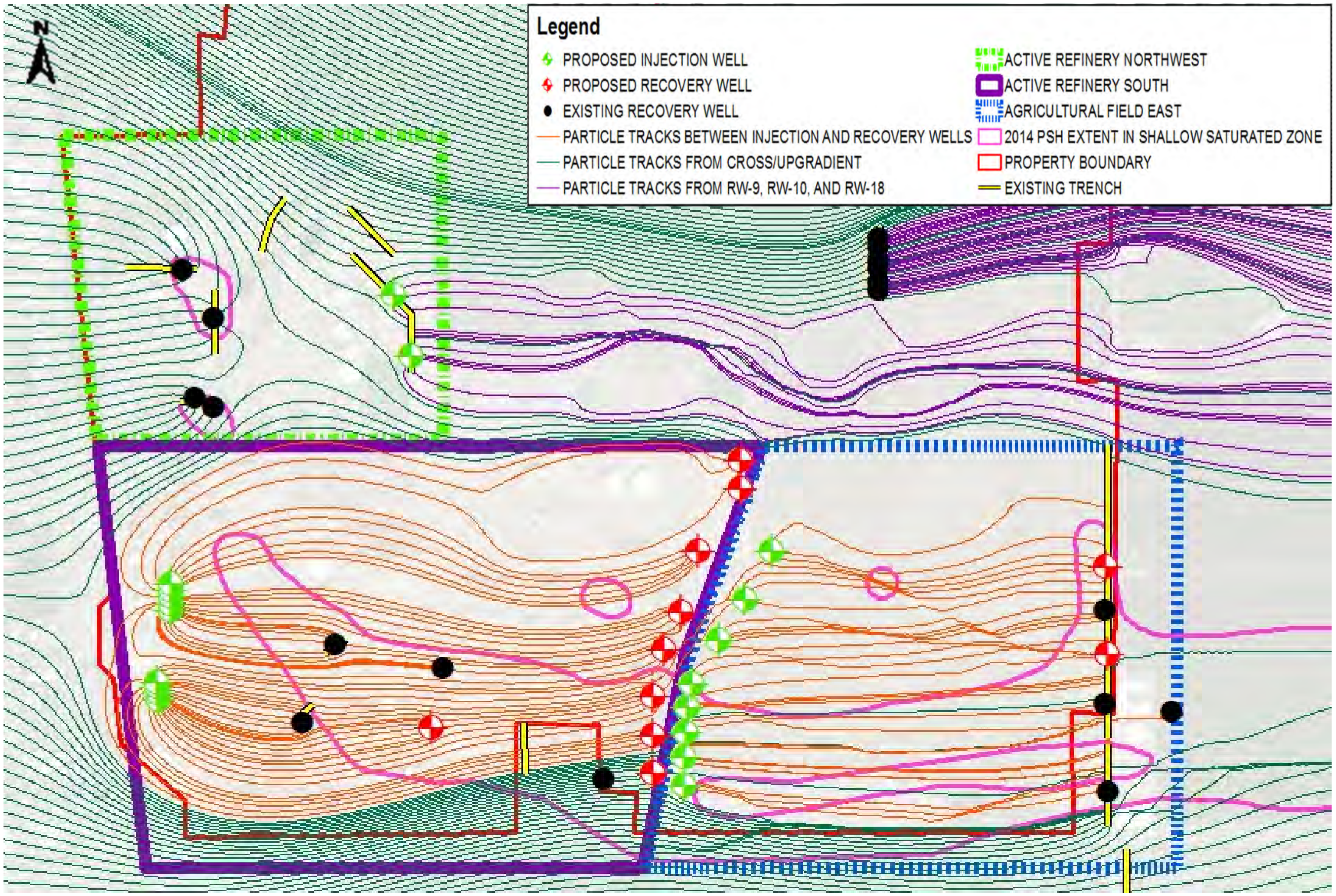
DUAL LOOP MODELED FULL-SCALE RECOVERY SYSTEM

Response to Comments to the April 06, 2020, NMED Approval Letter with Modifications,
Revised Groundwater and Phase-Separated Hydrocarbon Recovery System Enhancements: Reinjection Pilot Test Work Plan

Source: March 2018 Meeting Presentation with NMED and New Mexico Oil Conservation Division (OCD)

Revised Model Particle Tracks

- Particle tracks show the modelled pathways that groundwater will flow using the revised extraction and injection scenario.
- Model shows extraction will capture the injected water in the southern plume areas.
- Clean water injected into shallow water-bearing zone in RW-9/RW-10 and RW-18 will not be captured.

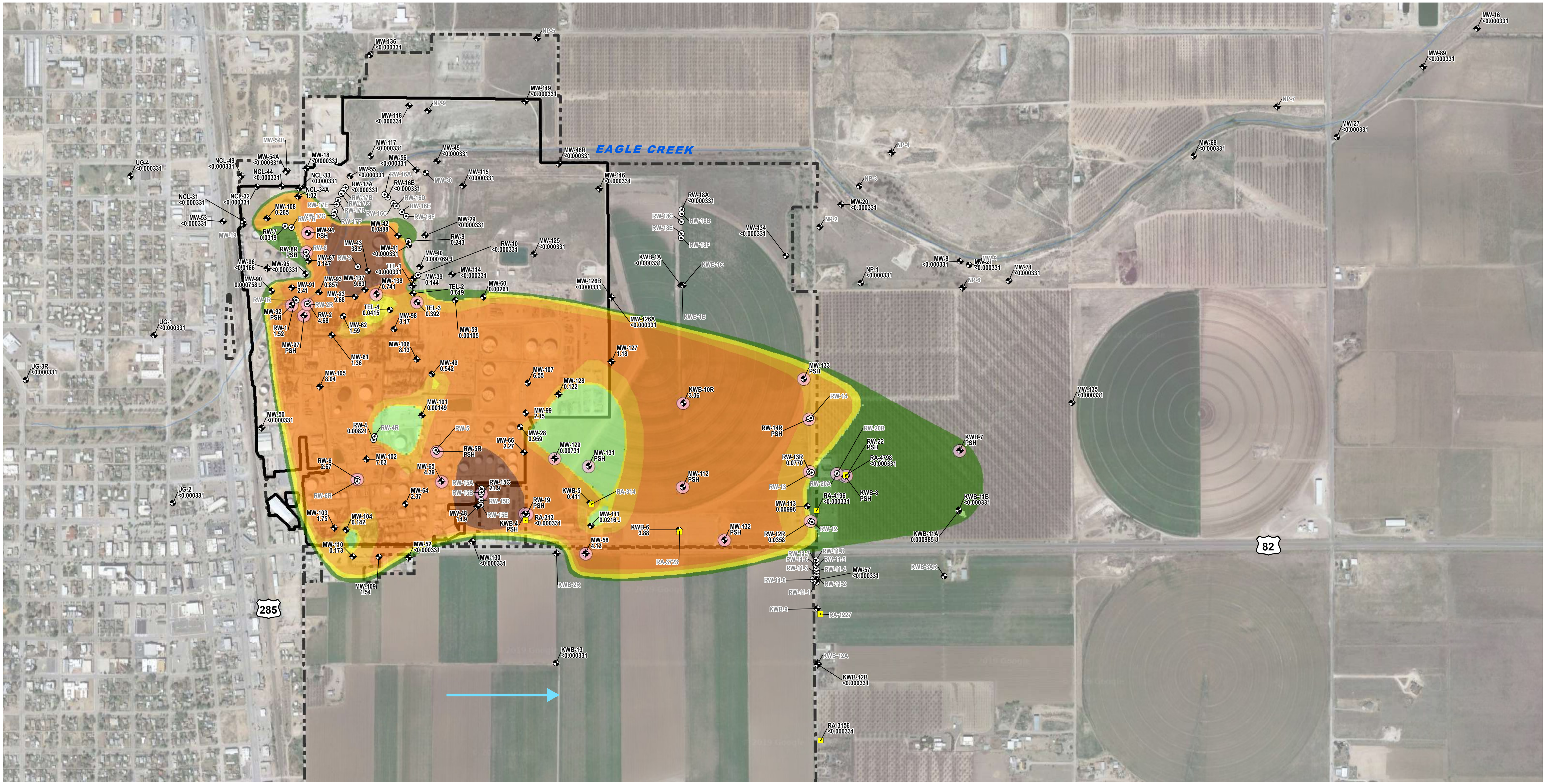


ATTACHMENT 2

DEPRESSED SULFATE CONCENTRATIONS WITHIN THE DISSOLVED HYDROCARBON PLUME

Response to Comments to the April 06, 2020, NMED Approval Letter with Modifications,
Revised Groundwater and Phase-Separated Hydrocarbon Recovery System Enhancements: Reinjection Pilot Test Work Plan

Source: Response to Comments to the July 22, 2019 Letter of Disapproval, Groundwater and Phase-Separated Hydrocarbon Recovery System Enhancements: Reinjection Pilot Test Work Plan



LEGEND

- MONITORING WELL
- RECOVERY WELL
- IRRIGATION WELL IN MONITORING PROGRAM
- **1.75** BENZENE CONCENTRATION
- **<0.000331** BENZENE NOT DETECTED ABOVE METHOD DETECTION LIMIT
- **PSH** PHASE-SEPARATED HYDROCARBON PRESENT IN WELL (≥ 0.03 FEET THICK)
- KWB-9 WELL NOT SAMPLED
- REFINERY FENCELINE
- FACILITY PROPERTY BOUNDARY (FENCELINE SHOWN WHERE COINCIDENT)
- GROUNDWATER FLOW DIRECTION
- PSH PRESENCE 2016-2018

NOTES:

1. ALL CONCENTRATIONS ARE IN MILLIGRAMS PER LITER (mg/L).
2. J = CONCENTRATION QUALIFIED AS AN ESTIMATED VALUE.
3. ALL MONITORING AND RECOVERY WELLS ARE SCREENED IN THE SHALLOW SATURATED OR VALLEY FILL ZONES. IRRIGATION WELLS INCLUDED IN THE MONITORING PROGRAM ARE SCREENED IN EITHER THE VALLEY FILL ZONE OR THE DEEP ARTESIAN AQUIFER.
4. BENZENE CRITICAL GROUNDWATER SCREENING LEVEL (CGWSL) = 0.005 mg/L

AERIAL IMAGERY SOURCE: GOOGLE EARTH PRO AND THEIR DATA PARTNERS, 3/12/2016.

BENZENE CONCENTRATION FROM 2018 FIRST SEMIANNUAL EVENT (mg/L)

- 0 - 0.0001
- 0.0001 - 0.001
- 0.001 - 0.01
- 0.01 - 0.1
- 0.1 - 1.0
- 1.0 - 10
- 10 - 100

0 500 1,000 Feet
1 " = 1,000 '
1:12,000

PROJECT:
NMED JULY 22, 2019 RESPONSE TO COMMENTS LETTER
HOLLYFRONTIER NAVAJO REFINERY LLC
ARTESIA REFINERY, EDDY COUNTY, NEW MEXICO

TITLE:
BENZENE ISOCONCENTRATION MAP
(FIRST 2018 SEMIANNUAL EVENT)

DRAWN BY:	MHORN	PROJ. NO.:	326693
CHECKED BY:	AELJURI	**FIGURE 1**	
APPROVED BY:	JSPEER		
DATE:	AUGUST 2019		

TRC
505 East Huntland Drive, Suite 250
Austin, TX 78752
Phone: 512.329.6080
www.trcsolutions.com

FILE NO.: 326693_1_BenzSpring.mxd

TRC - GIS

Coordinate System: NAD 1983 2011 StatePlane New Mexico East FIPS 3001 Ft US (Foot US)
Map Rotation: 0

Plot Date: 8/13/2019, 16:43:22 PM by MHORN -- LAYOUT: ANSI B(11"x17")
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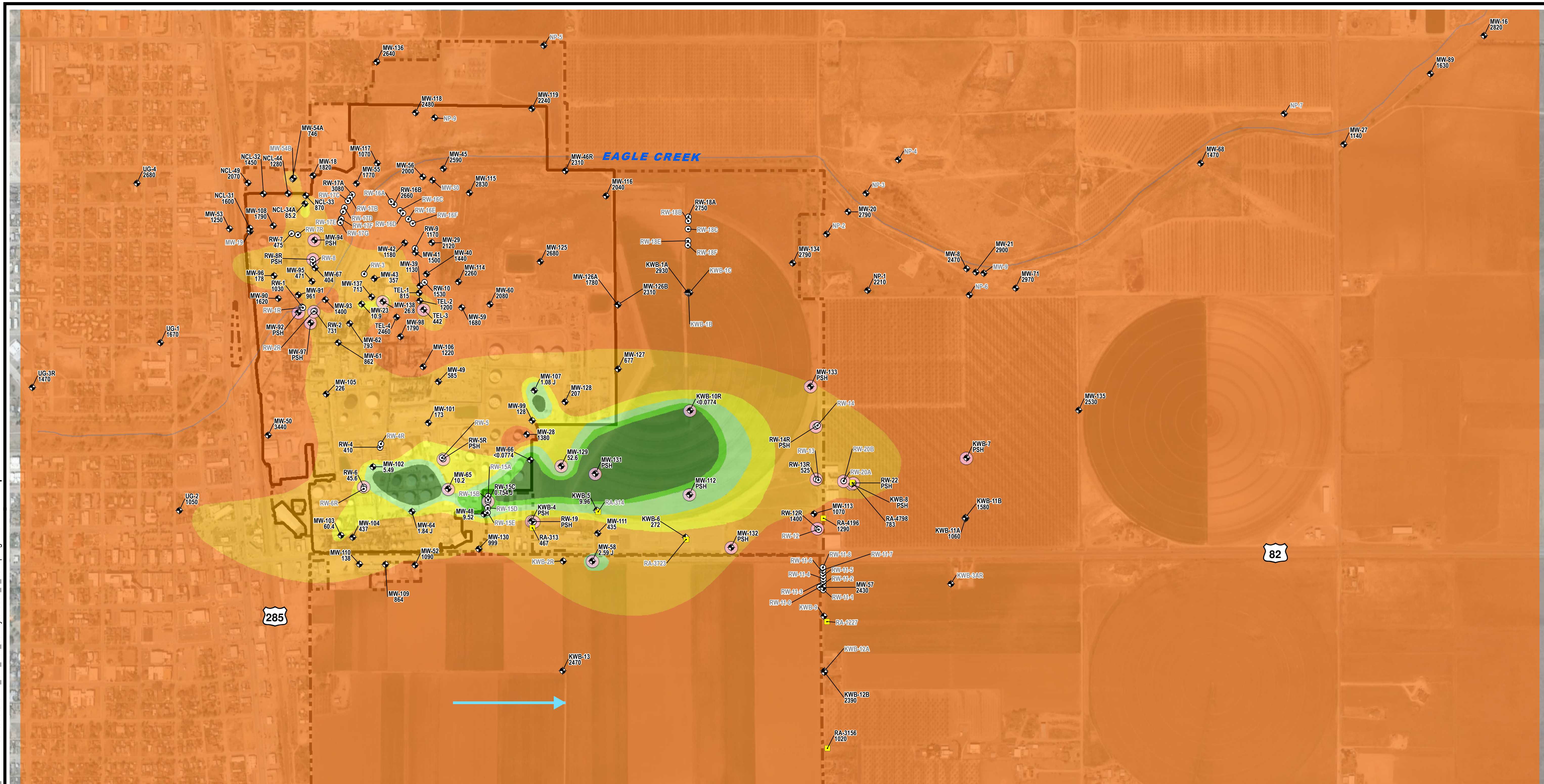

LEGEND

- MONITORING WELL
- RECOVERY WELL
- IRRIGATION WELL IN MONITORING PROGRAM
- **1030** SULFATE CONCENTRATION
- **<0.0774** SULFATE NOT DETECTED ABOVE METHOD DETECTION LIMIT
- **PSH** PHASE-SEPARATED HYDROCARBON PRESENT IN WELL (≥ 0.03 FEET THICK)
- KWB-9 WELL NOT SAMPLED
- REFINERY FENCELINE
- FACILITY PROPERTY BOUNDARY (FENCELINE SHOWN WHERE COINCIDENT)
- GROUNDWATER FLOW DIRECTION
- PSH PRESENCE 2016-2018

NOTES:

1. ALL CONCENTRATIONS ARE IN MILLIGRAMS PER LITER (mg/L).
2. J = CONCENTRATION QUALIFIED AS AN ESTIMATED VALUE.
3. ALL MONITORING AND RECOVERY WELLS ARE SCREENED IN THE SHALLOW SATURATED OR VALLEY FILL ZONES. IRRIGATION WELLS INCLUDED IN THE MONITORING PROGRAM ARE SCREENED IN EITHER THE VALLEY FILL ZONE OR THE DEEP ARTESIAN AQUIFER.
4. SULFATE CRITICAL GROUNDWATER SCREENING LEVEL (CGWSL) = 600 mg/L

SULFATE CONCENTRATION FROM 2018 FIRST SEMIANNUAL EVENT (mg/L)

- 0-0.1
- 0.1-1.0
- 1.0-10
- 10-100
- 100-1,000
- 1,000-10,000

0 500 1,000 Feet

1 " = 1,000 '

1:12,000

AERIAL IMAGERY SOURCE: GOOGLE EARTH PRO AND THEIR DATA PARTNERS, 3/12/2016.

PROJECT:

NMED JULY 22, 2019 RESPONSE TO COMMENTS LETTER
HOLLYFRONTIER NAVAJO REFINERY LLC
ARTESIA REFINERY, EDDY COUNTY, NEW MEXICO

TITLE:

SULFATE ISOCONCENTRATION MAP
(FIRST 2018 SEMIANNUAL EVENT)

DRAWN BY:	MHORN	PROJ. NO.:	326693
CHECKED BY:	AELJURI	**FIGURE 2**	
APPROVED BY:	JSPEER		
DATE:	AUGUST 2019		

TRC
505 East Huntland Drive, Suite 250
Austin, TX 78752
Phone: 512.329.6080
www.trcsolutions.com

FILE NO.: 326693_2_SulfSpring.mxd

Coordinate System: NAD 1983 2011 StatePlane New Mexico East FIPS 3001 Ft US (Foot US)
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TRC - GIS

TRC
505 E. HUNTLAND DR.
SUITE 250
AUSTIN, TX 78752
PH:512-329-6080

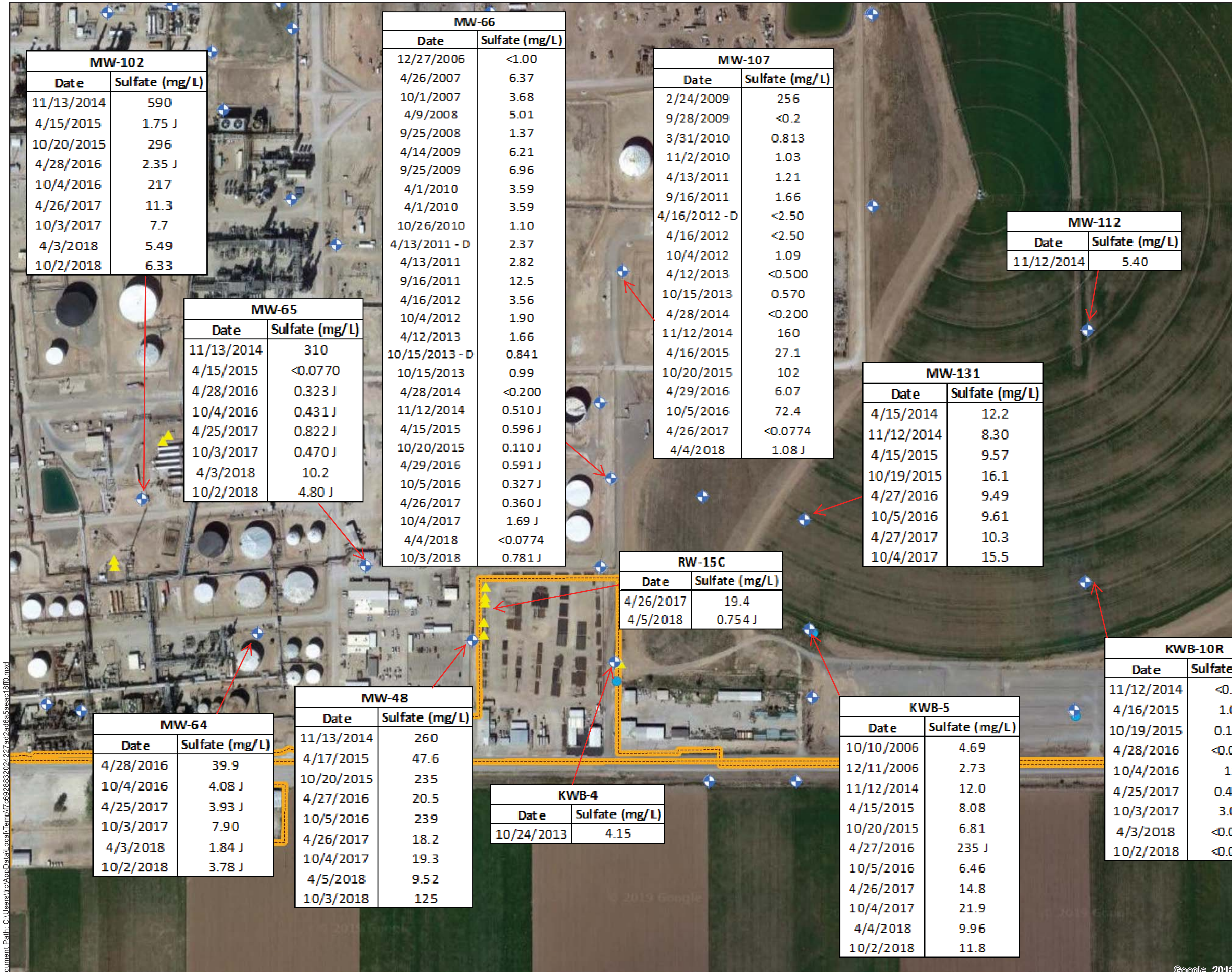
N

Due to this map being projected in the WGS84 EPSG:3857 one cannot accurately scale distances or areas from it. This map should be used for reference purposes only.

LEGEND

- Monitoring Well
- Recovery Well
- Irrigation Well
- Navajo Property
- Well ID and Historical Sulfate Concentrations

FIGURE 3 - HISTORICALLY DEPRESSED SULFATE CONCENTRATIONS, NMED JULY 22, 2019 LETTER, COMMENT 5b



MW-102

Date	Sulfate (mg/L)
11/13/2014	590
4/15/2015	1.75 J
10/20/2015	296
4/28/2016	2.35 J
10/4/2016	217
4/26/2017	11.3
10/3/2017	7.7
4/3/2018	5.49
10/2/2018	6.33

MW-66

Date	Sulfate (mg/L)
12/27/2006	<1.00
4/26/2007	6.37
10/1/2007	3.68
4/9/2008	5.01
9/25/2008	1.37
4/14/2009	6.21
9/25/2009	6.96
4/1/2010	3.59
4/1/2010	3.59
10/26/2010	1.10
4/13/2011 - D	2.37
4/13/2011	2.82
9/16/2011	12.5
4/16/2012	3.56
10/4/2012	1.90
4/12/2013	1.66
10/15/2013 - D	0.841
10/15/2013	0.99
4/28/2014	<0.200
11/12/2014	0.510 J
4/15/2015	0.596 J
10/20/2015	0.110 J
4/29/2016	0.591 J
10/5/2016	0.327 J
4/26/2017	0.360 J
10/4/2017	1.69 J
4/4/2018	<0.0774
10/3/2018	0.781 J

MW-107

Date	Sulfate (mg/L)
2/24/2009	256
9/28/2009	<0.2
3/31/2010	0.813
11/2/2010	1.03
4/13/2011	1.21
9/16/2011	1.66
4/16/2012 -D	<2.50
4/16/2012	<2.50
10/4/2012	1.09
4/12/2013	<0.500
10/15/2013	0.570
4/28/2014	<0.200
11/12/2014	160
4/16/2015	27.1
10/20/2015	102
4/29/2016	6.07
10/5/2016	72.4
4/26/2017	<0.0774
4/4/2018	1.08 J

MW-112

Date	Sulfate (mg/L)
11/12/2014	5.40

MW-65

Date	Sulfate (mg/L)
11/13/2014	310
4/15/2015	<0.0770
4/28/2016	0.323 J
10/4/2016	0.431 J
4/25/2017	0.822 J
10/3/2017	0.470 J
4/3/2018	10.2
10/2/2018	4.80 J

MW-131

Date	Sulfate (mg/L)
4/15/2014	12.2
11/12/2014	8.30
4/15/2015	9.57
10/19/2015	16.1
4/27/2016	9.49
10/5/2016	9.61
4/27/2017	10.3
10/4/2017	15.5

RW-15C

Date	Sulfate (mg/L)
4/26/2017	19.4
4/5/2018	0.754 J

MW-48

Date	Sulfate (mg/L)
11/13/2014	260
4/17/2015	47.6
10/20/2015	235
4/27/2016	20.5
10/5/2016	239
4/26/2017	18.2
10/4/2017	19.3
4/5/2018	9.52
10/3/2018	125

MW-64

Date	Sulfate (mg/L)
4/28/2016	39.9
10/4/2016	4.08 J
4/25/2017	3.93 J
10/3/2017	7.90
4/3/2018	1.84 J
10/2/2018	3.78 J

KWB-4

Date	Sulfate (mg/L)
10/24/2013	4.15

KWB-5

Date	Sulfate (mg/L)
10/10/2006	4.69
12/11/2006	2.73
11/12/2014	12.0
4/15/2015	8.08
10/20/2015	6.81
4/27/2016	235 J
10/5/2016	6.46
4/26/2017	14.8
10/4/2017	21.9
4/4/2018	9.96
10/2/2018	11.8

KWB-10R

Date	Sulfate (mg/L)
11/12/2014	<0.077
4/16/2015	1.03 J
10/19/2015	0.117 J
4/28/2016	<0.0774
10/4/2016	110
4/25/2017	0.475 J
10/3/2017	3.08 J
4/3/2018	<0.0774
10/2/2018	<0.0774

Coordinate System: WGS 1984 Web Mercator Auxiliary Sphere
Projection: Mercator Auxiliary Sphere
Datum: WGS 1984
False Easting: 0.0000
False Northing: 0.0000
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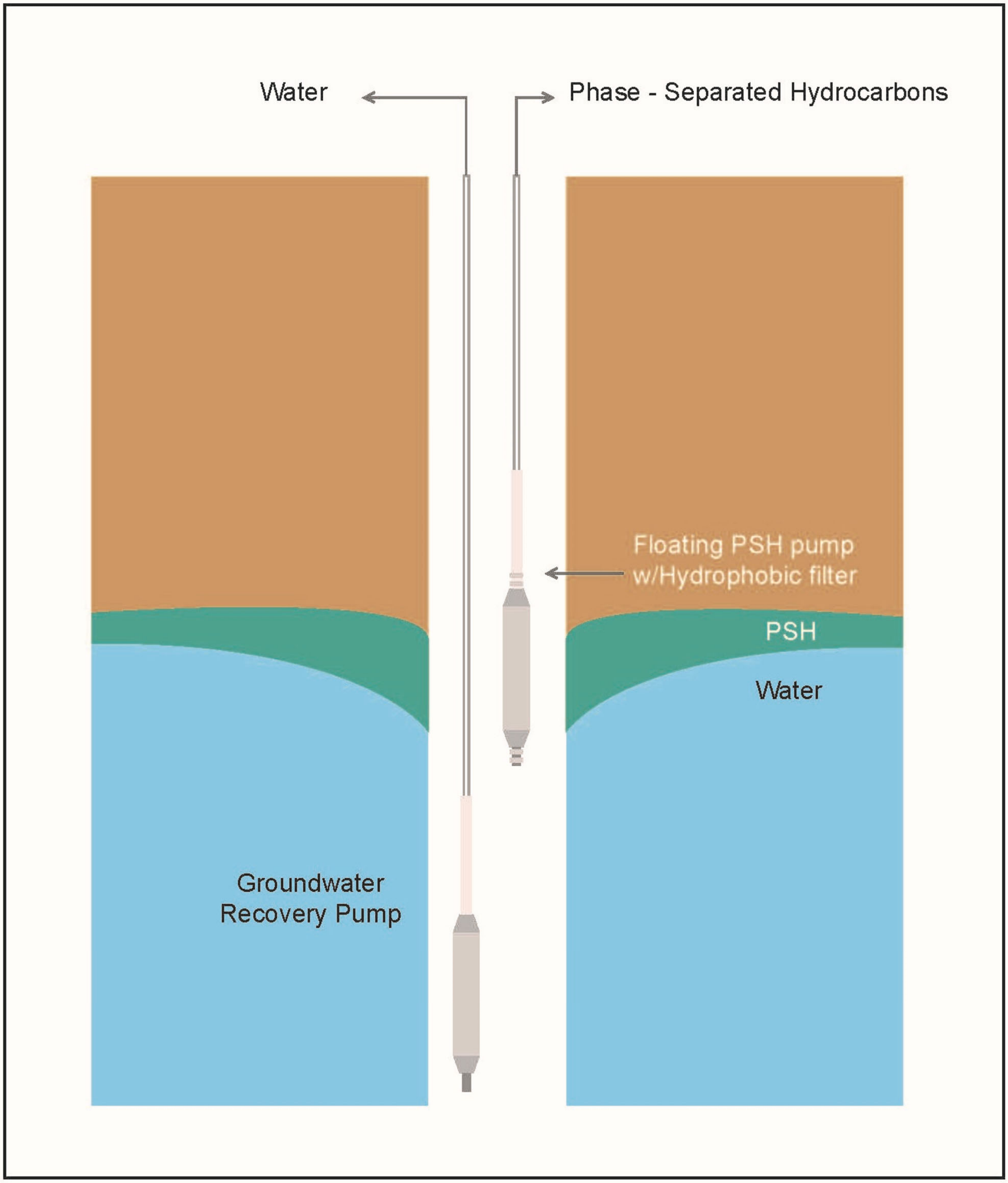
ATTACHMENT 3

DUAL (SEPARATE) PHASE GROUNDWATER AND PHASE-SEPARATED HYDROCARBON RECOVERY SCHEMATIC

Response to Comments to the April 06, 2020, NMED Approval Letter with Modifications*, Revised Groundwater and Phase-Separated Hydrocarbon Recovery System Enhancements: Reinjection Pilot Test Work Plan*

Dual (separate) Phase Groundwater and PSH Recovery Schematic



ATTACHMENT 4

REPLACEMENT PAGES FOR THE *REVISED GROUNDWATER AND PHASE-SEPARATED HYDROCARBON RECOVERY SYSTEM ENHANCEMENTS: REINJECTION PILOT TEST WORK PLAN*, DECEMBER, 2019

Response to Comments to the April 06, 2020, NMED Approval Letter with Modifications*, Revised Groundwater and Phase-Separated Hydrocarbon Recovery System Enhancements: Reinjection Pilot Test Work Plan*

Revised Groundwater and Phase-Separated Hydrocarbon Recovery System Enhancements: Reinjection Pilot Test Work Plan

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December 2019

Replacement Pages May 29, 2020

Prepared for:

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4.0 Pilot Test Setup

4.1 Test Locations

To test recovery and injection efficacy in areas that are representative of the conditions that will be addressed by the full-scale system, HFNR is planning to perform the pilot test in the East Field near existing wells RW-19 and MW-131 (proposed primary pilot test locations). The following selection criteria was used:

- Dissolved hydrocarbon (target high) and sulfate (target low) concentrations.
- Accessibility (underground and aboveground utilities, rig access, room for aboveground equipment, etc.).
- Impact to current and planned Refinery activities (pilot test equipment will be present underground and aboveground and will be accessed frequently).
- Geology and hydrogeology:
  - Pilot test injection, monitoring, and recovery wells will be oriented eastward, following groundwater flow direction.
  - Each of the pilot test location will be completed in one of the primary soil types of the shallow saturated zone (gravel and silty sand).
  - Wells within each pilot test area will be screened within the same, continuous coarse-grained lithologic zone to the degree feasible.
- Proximity to proposed well locations presented to NMED in the March 2018 "Groundwater Recovery and Reinjection System Upgrade – Groundwater Model Update".

The area around wells RW-19 and MW-131 contains PSH and dissolved-phase constituents at concentrations of the same magnitude or higher than what is expected to be recovered by the enhanced recovery system. The two proposed pilot test locations provide the opportunity to test injection, amendment, and recovery in two of the primary soil types (gravel and silty sand) in which the full-scale system will also be installed. These locations are also readily accessible and will have limited impacts to current and planned Refinery activities. Two alternate locations have been selected for pilot testing should initial field testing (gamma logging, soil borings, etc. as described below and in Section 5.2.2) indicate one or both primary test locations are not feasible. The proposed alternate pilot test locations will only be considered as needed and in the following order: 1) immediately north of recovery trench RW-15 and 2) south of MW-105, between MW-50 and MW-101. These alternate locations are shown on the figures provided in Appendix A. HFNR will notify NMED and OCD if a primary location is inappropriate, identify one of the proposed alternate locations, and obtain NMED acceptance of the alternate location prior to proceeding with the Pilot Test.

The exact location of the injection, monitoring, and recovery wells will be determined after completion of gamma logging of the existing wells in the area near RW-19 and MW-131 (discussed further in Section 5.2.2). Based on the geologic, geophysical, and contaminant migration investigation results from previous investigation in the East Field, preliminary pilot test locations for injection, recovery, and monitoring have been proposed with the intent of testing the effects of amendment and recovery in silty sand and gravel, both of which are prevalent in the observed preferential groundwater flow pathways in the East Field. Gamma logging is planned to be conducted to confirm that the resulting logs are consistent with the described geological descriptions. The borehole data will also be used to ensure that the gamma logs were not affected by subsurface utilities. Should borehole data indicate that a location is not appropriate, additional work will be performed to locate a suitable alternative. The lithology in the area near wells RW-19 and MW-131 will be further characterized from the borehole data obtained from the installation of the pilot study extraction, injection, and monitoring wells. The final locations of wells to be used in each of the two pilot test areas will be adjusted with the intent of having all wells within each pilot test area screened within the same, continuous coarse-grained lithologic zones, to the degree feasible based on the heterogeneous nature of the shallow geology. One pilot test area will target zones with more gravel (near RW-19) and the other pilot test area will target zones with more silty sand (near MW-131). The results of the gamma logging and any other geologic data collected during preliminary investigation will be provided with discussion in the Final Investigation Report (Pilot Test report) as described in Section 6.0.

4.2 Dissolved-Phase Conditions

Based on existing groundwater data from ongoing monitoring at the Refinery, the dissolved-phase hydrocarbon constituents are being actively degraded under anaerobic conditions and most likely by SRBs. The following observed groundwater conditions and trends are primary and secondary lines of evidence that hydrocarbon degradation by SRBs is actively occurring:

- Inverse concentration correlation between sulfate and the following dissolved-phase hydrocarbon constituents, specifically in the East Field: benzene, ethylbenzene, toluene, and xylenes (BTEX), naphthalene, gasoline range organics (GRO), and diesel range organics (DRO).
    - Sulfate concentrations upgradient (west) of the Refinery appear to range between 1,000 and 2,000 mg/L, while sulfate concentrations within the hydrocarbon plume below the East Field range from 10 to 100 mg/L and are non-detect in some wells.
    - The inverse concentration correlation indicates SRBs are utilizing sulfate to degrade hydrocarbons in both dissolved and adsorbed phases (note that the sulfate

demand of dissolved-phase concentrations is too low to exceed the upgradient supply of sulfate).

- Anaerobic conditions as oxidation reduction potential (ORP) is less than -100 millivolts (mV).
- Presence of black particulates in and/or slightly grey turbid purge water during groundwater sampling activities indicates iron sulfide precipitants.
- Apparent preferential degradation of more readily degraded isomers in isomer pairs, for example:
  - o-xylene detected at concentrations less than 1/10th the concentration of m/p-xylenes in groundwater samples.
  - 1,3,5-trimethylbenzene detected at concentrations less than 1/10th the concentration of 1,2,4-trimethylbenzene in groundwater samples.

These conditions indicate that an amendment with bioavailable sulfate has the potential to increase the degradation rate of hydrocarbons. In addition to bioavailable sulfate, nitrogen in the form of ammonia may be added to the system to amend the two most likely rate-limiting nutrients. The nitrogen source will only be added if baseline monitoring indicates there is insufficient nitrogen present in the Shallow Saturated Zone (i.e., total Kjeldahl nitrogen [TKN] <10 mg/L).

5.2.1 Baseline Groundwater Quality Evaluation

Baseline trend data will be collected from existing monitoring wells in the area at least 14 days but no more than 30 days prior to initiation of the pilot test. The baseline trend data will be collected to evaluate existing groundwater quality and potentiometric surface. Results of baseline water quality testing will be used to (1) calculate the range of dosing of amendment(s) in the water treatment area and (2) determine baseline conditions to be used to evaluate the effectiveness of the amendment(s) in reducing dissolved-phase concentrations in the vicinity of the reinjection zone during the pilot test. Additionally, water level data recorded during the baseline period may be utilized to evaluate mounding and/or drawdown changes in groundwater levels observed during the pilot test. The following data will be collected and evaluated to establish baseline trends prior to the treatment efficiency test:

- Groundwater elevation;
- Presence and apparent thickness of PSH;
- Site-specific constituents of concern (COCs) concentrations: BTEX, 1,2,4-trimethylbenzene, 1,3,5-trimethylbenzene, MTBE, naphthalene, GRO, and DRO;
- Monitored natural attenuation (MNA) laboratory-measured parameter concentrations: sulfate, TKN, total organic carbon (TOC), alkalinity, ferrous iron, sulfide, and magnesium;
- MNA field-measured parameter concentrations: conductivity, ORP, dissolved oxygen (DO), temperature, depth to water and SRBs (qualitative measurement);
- Qualitative acid-producing bacteria analysis (e.g., BART Hach Tests) and qualitative sulfate-reducing bacteria analysis (e.g., BART Hach Tests);
- Barometric pressure; and
- Precipitation.

Baseline water level and water quality data will be measured in existing wells nearest the pilot test. This includes RW-19 and MW-131 and respective upgradient, proximal downgradient, crossgradient, and peripheral downgradient wells as defined in Section 5.2.7 and below:

- RW-19 Pilot test area
    - Within pilot test area: RW-19 and KWB-4
    - Upgradient wells: MW-99, MW-48, and RW-15C
    - Proximal downgradient well: KWB-5 and MW-111

- MW-131 Pilot test area
  - Within pilot test area: MW-131
  - Upgradient wells: MW-66, MW-99, and MW-129 (Note that only one sample at MW-99 will be collected during each sampling event, but the results will be used in the evaluation of both pilot test areas.)
  - Proximal downgradient well: MW-112

Groundwater levels will be measured in each well listed above using an oil-water interface probe and a pressure transducer, as described in Section 5.3. Groundwater levels will be compared to historical groundwater information obtained during semi-annual groundwater monitoring events, which are ongoing at the Refinery. Laboratory and field parameter data will only be collected from wells located outside the pilot test area that contain less than 0.30 feet of PSH in accordance with the *2018 Facility-Wide Groundwater Monitoring Work Plan* (2018 FWGMWP). Groundwater quality data from wells within each Pilot Test area (i.e., KWB-4/RW-19 and MW-131) are critical for the baseline monitoring and will be sampled even if there is more than 0.3 feet of PSH present.

Barometric pressure will be recorded to a sensitivity of 0.01 inches of mercury using a barometric pressure probe installed at a central location at the Refinery. The data will be recorded starting two weeks before the initiation of the injection test and continuing until two weeks after conclusion of the injection test. Precipitation data will be recorded for the period starting two weeks before the injection test and continuing until two weeks after conclusion of the injection test. Precipitation data will be measured using either the Refinery's local weather station or a rain gauge installed at the Refinery.

5.2.2 Installation of Injection, Recovery, and Monitoring Wells

Injection and recovery wells will be installed as part of the pilot test. One injection well and one recovery well will be installed at each pilot test area (i.e., a total of two new injection wells and two new recovery wells) near existing wells RW-19 and MW-131, as shown on Figures 2a and 2b. The exact layout of the injection, monitoring, and recovery wells may be adjusted based on the results of gamma logging and potential additional investigation in the pilot test area. One injection well and one recovery well will be used for each pilot test, with each injection well installed upgradient of the associated recovery well. Injection and recovery wells will be separated by a minimum distance of 200 feet to ensure that the radius of influence from recovery drawdown and injection mounding do not overlap. The reason for separating the injection and capture zones is to mimic operation of the full-scale system and to prevent biasing the pilot test results by creating any preferential pathways or circulation cells. To monitor the potentiometric surface and COC/MNA data as listed in Section 5.2.7, additional monitoring wells will also be installed between each injection and recovery well at an approximate spacing of 40 feet, and one monitoring well will be installed approximately 40 feet downgradient of each recovery well. For the pilot test area near MW-131, one additional monitoring well will be installed approximately 170 feet upgradient of the injection well and approximately 230 feet downgradient of the recovery well in accordance with NMED comments provided during discussions on October 3, 2019 and November 4, 2019. The proposed layout of the wells proposed for the pilot tests are shown on Figures 2a and 2b.

Gravel seams and silty sand zones are present in the shallow saturated zone in the East Field and serve as preferential pathways for groundwater and contaminant transport. The pilot test near existing well RW-19 is designed to target this gravel seam for injection and recovery, while the pilot test near existing well MW-131 is designed to target the shallow saturated zone where silty sand is more predominant (the gravel seam is limited or not present) for injection and recovery. The top of the gravel seam at RW-19 occurs from approximately 18 to 24 feet bgs. A gamma-log study will be conducted on existing monitor wells in the area prior to installation of the pilot test injection and recovery wells to verify the gravel seam and silty sand presence, depth, thickness, and extent in each pilot test area. Injection wells will be designed based on the gamma logging results, using lithology from the CME results and/or lithology from borings installed prior to the pilot test to evaluate the pilot test area, if deemed necessary. The injection wells will be constructed of stainless steel casing and screen, and will be screened below the water table and across the target lithologic zone. A proposed construction diagram for the injection wells is provided in Appendix B. Installation details for the injection and recovery wells are discussed in Section 5.3.

New recovery wells will be installed in the same configuration and method as was done for the Phase II recovery system (see well construction diagram provided in Appendix B). A 14-inch diameter boring will be drilled and three separate well casings will be installed within the boring. These casings will be used for water recovery (4-inch diameter casing with total fluid pump), PSH recovery (4-inch diameter casing with skimmer pump), and measurement (1-inch diameter casing with instrumentation). Recovery wells will include instrumentation as used in the Phase II recovery wells to allow remote monitoring and control. If PSH accumulates in the recovery wells, skimmers or total fluid pumps will be used to remove PSH from the recovery wells in the same manner as the Phase II wells. The groundwater recovery pump intake will be set below the water table surface and operated to prevent intake of PSH. If significant PSH accumulates in a pilot test recovery well, it will automatically be skimmed from its own casing with the floating PSH pump and pumped directly to a small tote located near the recovery well (see Figure 4 for a representative schematic of the groundwater recovery and PSH pumps depths relative to groundwater and PSH levels). The groundwater recovery pump intake will be installed so a maximum drawdown of two feet below the smear zone is achieved. The pump intake must remain below the water surface so that air is not entrained during extraction and to prevent pump malfunction. The lowest historical groundwater elevations observed near each proposed recovery well indicate the bottom of the smear zone (pending recovery well installation logging observations) and are provided below:

- MW-131: 3338.88 feet above mean sea level (amsl) in April 2019 (21.72 feet bgs)
- RW-19: 3333.37 feet amsl in March 2019 (35.20 feet bgs)

Any PSH present in pilot test monitoring or injection wells will be measured, and if removed, stored temporarily in small totes near the recovery well so that the recovered volume can be tracked separately from the rest of the current recovery system.

For purposes of complying with RCRA, the injection wells are authorized by rule (permit by rule) as provided in 40 CFR §144.23(c) and 20.6.2.5004 NMAC since they are part of a RCRA Corrective Action.[1,2]. OCD Form C-108 (Application for Authorization to Inject) is included as Appendix C for both wells for informational purposes. OCD Underground Discharge System (Class V Inventory Sheet) is included as Appendix D for both wells for informational purposes. EPA Form 7520-17 (Class V Well Pre-Closure Notification Form) is included as Appendix E for both wells for informational purposes. The proposed recovery wells will be installed as permanent recovery wells and may be used as part of the full-scale system. The proposed injection and monitoring wells will also be installed as permanent wells but may be recommended for abandonment upon completion of the pilot test. HFNR will propose to retain or abandon the wells in the Final Investigation Report and will not abandon the wells without concurrence from NMED and OCD.

5.2.3 Aquifer Testing

Pump testing and injection testing will be conducted at each pilot test area. The existing recovery system, except for RW-19, will remain in operation during installation of aquifer testing equipment and throughout the aquifer and pilot tests. Operation of the existing recovery system is not expected to affect the aquifer tests or pilot test based on the radius of influence observed during routine groundwater monitoring. The East Field is no longer irrigated and will not be irrigated during the aquifer tests or pilot test.

[1] As provided in 40 CFR §144.23(c), injection wells used to inject contaminated ground water that has been treated and is being injected into the same formation from which it was drawn are authorized by rule for the life of the well if such subsurface emplacement of fluids is approved by EPA, or a State, pursuant to provisions for cleanup of releases under the Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA), or pursuant to requirements and provisions under RCRA.

[2] As provided in 20.6.2.5004 NMAC, Class IV wells are prohibited, except for wells re-injecting treated ground water into the same formation from which it was drawn as part of a removal or remedial action if the injection has prior approval from the EPA or the Department under CERCLA or RCRA.

5.2.3.1 Pump Test

A step-drawdown and constant-rate pump test will be performed at each pilot test area near wells RW-19 and MW-131. Pump tests will be conducted from one of the pilot test monitoring wells located between the injection and recovery wells at each pilot test area so that observation wells are present to the east and west of the pumping well. The pump tests are not necessary for the design or operation of the pilot test but will be conducted to further characterize hydrogeologic properties of the Shallow Saturated Zone and confirm the injection test results.

An electric, submersible pump capable of pumping at rates of 4 to 15 gallons per minute (gpm) will be installed at the pumping well. The pump and motor will be sized to achieve the specified injection rate ranges with consideration of vertical lift and friction losses. A Grundfos Redi-Flo4 variable frequency drive pump or equivalent pump will be used; it will have a variable frequency drive motor so the flow rate can be controlled by adjusting the power input to the pump.

Pressure transducers will be placed in the injection wells, monitoring wells, and recovery wells in the pilot test area to measure the groundwater level. Within 60 minutes prior to commencement of the pump tests, static water levels will be recorded at each injection well, monitoring well, and recovery well included in the pilot test using an oil-water interface probe. Each pressure transducer will be installed at least 60 minutes before the test begins. Immediately prior to the test, the water level at each pressure transducer will be set to 0.00 feet to facilitate observation of water level changes. The pressure transducers will remain in the wells and record water level measurements throughout the pump tests.

The step-drawdown test will be performed to determine a sustainable pumping rate for the constant-rate test. The step-drawdown test involves pumping the well at a series of pre-defined, successively increasing, equal duration constant rates and continuously recording drawdown in the pumped well and observation wells. The data from each step will be graphed during the test with time on a logarithmic x-axis and water level of the injection well on a linear y-axis. During each step, the water level should decrease rapidly at the beginning of the test and stabilize as the test proceeds. When the water level essentially stabilizes, the pump rate will be increased to the next step. Up to a maximum of four steps may be performed. The duration of each step will be 30 to 120 minutes to provide enough time for the potential stabilization of the pumping water level. The anticipated pumping rates for the initial three steps will be 4 gpm, 8 gpm, and 12 gpm, but these rates are subject to change based on observed conditions during the test. After the pump is shut off at the completion of the step-drawdown test and prior to beginning the constant-rate test, the water level in the pumping well should recover to the static water level or at least 95% of the drawdown at the end of the test. During this recovery period, the step-drawdown data will be evaluated to determine the sustainable pumping rate of the well for the constant-rate test.

The constant-rate test will be conducted with a sustainable pumping rate determined from the step-drawdown test. The desired pumping/discharge rate will be attained rapidly and monitored frequently to ensure the rate does not vary more than a few percent. Rate decreases with increasing drawdown and may suddenly change with interception of a boundary or heterogeneity in the saturated zone. The water level in the pumping well will also be checked frequently to ensure drawdown does not reach the pump. The duration of the constant-rate test will be at least 24 hours, followed by an 8-hour recovery phase after cessation of pumping (or until water levels recover to 90% of the maximum drawdown). However, the constant-rate test may need to be terminated earlier if unanticipated drawdown occurs and a constant rate cannot be maintained for the planned test duration. The pilot test wells are designed for completion of the pilot test and are not optimal for pump testing (i.e., they are not screened across the saturated thickness of the Shallow Saturated Zone).

The pump tests will begin once all equipment has been installed and tested, and the static water levels have been measured. The injection pump, pressure transducer data loggers, and synchronized stopwatches will be activated simultaneously.

For both pump tests, the water level in the injection wells, monitoring wells, and recovery wells will be monitored using pressure transducers set at a linear data recording frequency of 30 seconds per reading at the pumping well and observation wells during the step-drawdown tests, constant-rate tests, and associated recovery phases. The water level data from the data logger will be monitored periodically to confirm the system is operating properly and to evaluate the test results. Manual gauging will be completed at regular intervals using an oil-water interface probe to confirm the pressure transducer measurements. Details regarding manual water level measurements are provided in Section 5.3.

The pumping rate will be measured using a totalizing flow meter at the pumping well that is also capable of recording flow rate. Adjustments will be made as necessary using the pump controller to achieve a constant pumping rate.

All equipment placed within each well such as the pressure transducer data loggers and oil-water interface probe will be decontaminated according to the procedure in Section 5.3.6 at the completion of the recovery phase of the constant-drawdown test. Purged groundwater generated during the pump tests will be managed as described in Section 5.3.7.

5.2.3.2 Initial Injection Test

A series of injection tests will be performed utilizing the proposed injection wells at each pilot test area near wells RW-19 and MW-131. A minimum of one test per area will be performed, and up to a maximum of four separate injection tests may be performed. Goals of the injection tests are to determine the optimal injection rate and to observe hydrogeologic response after repeated injections. The variable injection test rates and lengths will allow determination of the best way to influence the peripheral monitoring locations. The results of the initial injection test will be used to optimize pilot test injection design and ultimately the full-scale system upgrade design.

Each injection test will be performed and analyzed similar to an aquifer step-drawdown test. Extracted water from the newly-installed recovery wells will be used to perform each injection test. Water will be discharged into each injection well at the mid-point of the well screen interval or at the top of the well casing seal. The discharge line will be plumbed through a well seal rated to contain upward pressure that may be created during injection.

An electric, submersible pump capable of pumping the injection rate range of 4 to 15 gpm will be installed at the recovery well. The target injection rate will be 12 gpm based on initial full-scale system design, and the rate will be optimized during the pilot test. The pump and motor will be sized to achieve the specified injection rate ranges with consideration of vertical lift and friction losses. A Grundfos Redi-Flo4 variable frequency drive pump or equivalent pump will be used; it will have a variable frequency drive motor so the flow rate can be controlled by adjusting the power input to the pump. The recovery pumps will be connected to a Programmable Logic Controller which will also collect data from pressure transducers (as described in the next section) to control recovery and injection rates.

Pressure transducers will be placed in the injection wells, monitoring wells, and recovery wells in the pilot test area to measure the groundwater level. Within 60 minutes prior to commencement of the injection test, static water levels will be recorded at each injection well, monitoring well, and recovery well included in the pilot test using an oil-water interface probe. Each pressure transducer will be installed at least 60 minutes before the test begins. Immediately prior to the test, the water level at each pressure transducer should be set to 0.00 feet to facilitate observation of water level changes. The pressure transducers will remain in the wells and record water level measurements throughout and after the injection tests for a period of at least 24 hours.

The basic procedure for each injection test involves conducting three or more steps of injection at rates that are incrementally increased during each step. A constant injection rate will be maintained during each step. The data from each step will be graphed during the test with time on a logarithmic x-axis and water level of the injection well on a linear y-axis. During each step, the water level should increase rapidly at the beginning of the test and stabilize as the test proceeds. When the water level essentially stabilizes, the injection rate will be increased to the next step. The final step should result in a water level in the injection well that is near the top of the well casing, depending on formation characteristics near the well.

Each injection test will consist of a minimum of three successive and increasing injection rate steps. During each step, the injection rate will remain constant. The anticipated injection rates for the first three steps of the test are 1, 4, and 8 gpm based on NMED comments provided in the July 22, 2019 letter. These rates are subject to change based on observed conditions during the test (i.e., the initial injection rate will be 1 gpm and will be increased to a maximum of 12 gpm depending on the capacity of the injection well). The wellhead will be configured to allow the installation of a pressure transducer so that that pressure can be monitored throughout the duration of the test. Care will be taken not to exceed pressure suitable for the wellbore and formation. The duration of each step will typically be 60 to 180 minutes such that the entire injection test can be completed in one day. Once the water level during a step is relatively stable, the injection rate will be increased.

The injection test will begin once all of the equipment has been installed and tested, and the static water levels have been measured. The injection pump, pressure transducer data loggers, and synchronized stopwatches will be activated simultaneously.

The water level in the injection wells, monitoring wells, and recovery wells will be monitored using pressure transducers set at a linear data recording frequency of ten seconds per reading at wells near the injection well and on a logarithmic frequency at wells near the recovery well. A logarithmic recording frequency is not required as the early time data is of no particular interest during an injection test. The water level data should be monitored from the data logger as frequently as possible to confirm the system is operating properly and to evaluate the test results. Manual gauging will be completed at regular intervals using an oil-water interface probe to confirm the pressure transducer measurements. Details regarding manual water level measurements are provided in Section 5.3.

The injection rate for each successive step should be increased to the planned rate as quickly as possible, and the injection rate should be monitored and recorded as frequently as practical until the target injection rate has been achieved and stabilized. The injection rate will be measured using a totalizing flow meter at the injection wells that is also capable of recording flow rate. Adjustments should be made to achieve a constant injection rate. The injection rate can be adjusted using the pump controller. Once the injection rate has stabilized, it will be monitored and recorded every 30 minutes.

After the injection test is complete, water levels in the injection wells, monitoring wells, and recovery wells will be recorded until levels reach static conditions or recovery has occurred for the same time duration as injection. This data will be recorded using the pressure transducer data loggers.

All equipment placed within each well such as the pressure transducer data loggers and oil-water interface probe will be decontaminated according to the procedure in Section 5.3.6 at the completion of the test.

5.2.4 Treatment Efficiency Pilot Test Equipment and Process Description

During the treatment efficiency pilot tests, recovered water from the new recovery wells will be utilized as a treatment and injection water source. Water should not be oxygenated to the extent practicable during recovery and transfer to the amendment point and injection well. In order to accomplish this, the system will be installed with continuous piping and minimal plumbing in order to minimize turbulence. The line will also be buried or insulated to minimize temperature fluctuations. Mitigating temperature fluctuations minimizes potential for changes in reduction/oxidation (redox) conditions. The lines will be fitted with a pressure-controlled actuator valve to shut off flow if a loss in pressure is detected.

The aboveground storage tank containing the amendment(s) in each injection area around RW-19 and MW-131 will include a 5,000-gallon concentrated sulfate solution. Connected to this tank on the discharge side will be the following: injection manifold, flow meter (totalizer and rate), sample port, pressure gauge, sulfate injection port, inline mixer (can be eliminated if access to injection well header sample point is convenient), post injection sample port, and manifold to injection well(s). Additionally, a metering pump will be connected for addition of the amendment(s) into the system. Table 1 details sulfate and ammonia (if used) addition rates based on injection rates and targeted sulfate formation concentrations. Metering pumps are very sensitive to out of range injection pressures; pressures will be very closely monitored throughout the duration of the pilot test. The injection pressure will be whatever is needed to inject at a rate consistent with the extraction rate, but HFNR expects the injection pressure will not exceed 5 psi.

5.2.5 Treatment Efficiency Evaluation

To enhance the rate of naturally occurring anaerobic degradation in the pilot test areas, sulfate and nitrogen will be added to the extracted groundwater stream. To prevent fouling of the injection system and injection well, it is critical that the redox condition of the extracted water remains anaerobic throughout the recirculation process, to the degree feasible. The following measures will reduce aeration of the recirculated water: ensuring all connections maintain an air-tight seal; selecting flow meters, pumps, and fixtures that minimize turbulence, inducted air flow, and pressure drops; capping the injection and recovery wells; and injecting through drop tubes that extend below the groundwater level within injection wells to prevent oxidization of injected anaerobic water. Additionally, metal plumbing fittings and manifolds will be minimized so any oxygen that may be inadvertently introduced to the recirculation system does not oxidize the ferrous iron and foul the recirculation plumbing or wells. Air leaks in these recirculation systems are obvious (creates hissing sound associated with air aspiration) and will be repaired immediately.

Enhanced anaerobic biodegradation (EAB) systems are generally designed to adjust groundwater sulfate concentrations to conditions upgradient of the Refinery which are most favorable for the indigenous microbes. The sulfate groundwater concentration of 1,700 mg/L observed upgradient of the Refinery (average of four upgradient wells as measured during April 2018 monitoring event) may be difficult to meet with traditional EAB recirculation system components; therefore, the system will be designed to increase the groundwater concentration from existing low sulfate concentrations (<20 mg/L in MW-131) to approximately 1,000 mg/L or greater, as possible. These increased concentrations will be sufficient to restore and support robust microbial activity.

Table 1 provides sulfate addition rates based on a stock sulfate solution concentration of approximately 3.1% (Epsom Salt approximately 8%). The stock solution will be prepared by mixing 6,000 pounds of Epsom Salt in 4,000 gallons of water in a 5,000-gallon poly tank. The Epsom Salt will be added to a 95-gallon mixing drum fed with a water stream from the mixing tank, and the resulting slurry will be pumped to the top of the storage tank. In addition to sulfate, a small amount of additional nitrogen in the form of ammonia will be added to eliminate nitrogen as a rate-limiting constituent. Ammonia will only be added if baseline monitoring indicates there is insufficient nitrogen present in the Shallow Saturated Zone (i.e., TKN <10 mg/L). The ammonia will be added through the same mixing drum as the Epsom Salt. The ammonia source will be household unscented and surfactant free 9% ammonium water. The nitrogen concentration in the sulfate tank will be adjusted to approximately 50 mg/L for a targeted formation concentration of 10 to 25 mg/L. After in situ dilution/mixing conditions are measured, both sulfate and ammonia injection rates will be adjusted to maintain an adequate supply of nitrogen and sulfate.

Using an initial injection rate of approximately 10 gpm (subject to change based on injection tests), the sulfate dosing rate from the stock tank will be 0.63 gpm or 900 gallons per day of stock solution. It is anticipated that the stock tank will initially be recharged every four days. However, as the pilot test progress, the rate of sulfate demand, as determined by sulfate concentrations in the wells downgradient of the injection wells, is expected to decrease, resulting in an increasingly slow rate of sulfate addition.

To monitor the distribution of the amendments during the initial stage of injection, sodium-bromide will be added to the injectate to be used a tracer in the formation. The sodium-bromide will be added through the same mixing drum as the Epsom Salt. The concentration of sodium-bromide in the amendment tank will be approximately 25 mg/L for a targeted formation concentration of 5 to 10 mg/L. Magnesium and conductivity will also be used as tracers throughout the pilot test.

5.2.6 Treatment Efficiency Test Procedure

Injection flow rate and specific capacity determined in the initial injection test will be utilized to determine injection rates during the treatment efficiency portion of the pilot test. The newly-installed injection and recovery wells will be connected to the closed-loop system, along with the tank containing the amendment(s) and the chemical metering pump, described above. The groundwater extracted from the recovery well will provide source groundwater for amendment and reinjection. Any PSH present in the extracted groundwater will be removed with an oil-water separator prior to entering the amendment tank. A diagram of the pilot test closed-loop system can be found in Figure 3.

Effluent from the recovery well will be plumbed to the amendment tanks at the injection wells via a series of below grade, hard-piped lines. The estimated flow rate of effluent supplied to the injection system will be between 1 and 15 gpm, to be determined based on injection well testing and hydrogeologic information.

Fluid received from the recovery well will ultimately be injected into the injection well via an electric pump, after treatment with the amendment(s). An electric, submersible pump capable of the injection rate will be installed on the supply line from the recovery well. The pump and motor will be sized to achieve the specified injection rate with consideration to vertical lift and friction losses. A Grundfos Redi-Flo4 variable frequency drive pump or equivalent pump will be used; it will have a variable frequency drive motor so adjusting the power input to the pump can control the flow rate.

An inline totalizing and flow rate meter will be used to measure the injection rate. A flow meter will be installed at each injection well.

Any PSH that accumulates in the recovery wells will be measured on a weekly basis and, if necessary, removed from the recovery well using a skimmer pump and pumped to a small tote staged near the recovery well. The PSH thickness and recovered volume will be recorded for the duration of the pilot test to assist in evaluating any improvement to PSH recovery as a result of the test. Any PSH present in extracted groundwater will be removed with an oil-water separator prior to entering the amendment tank.

5.2.7 Groundwater Monitoring

To effectively monitor and adjust the groundwater conditions and associated sulfate feed rates, monitoring wells will be utilized to monitor conditions downgradient of the injection wells and screened typically 25 to 30 feet bgs in the mixing zone (i.e., within and below the target lithologic zone which injection and recovery wells will be screened). Upgradient and downgradient wells will be monitored throughout the treatment efficiency pilot test to determine the maximum extent of treated groundwater impact.

In addition to new monitoring wells that will be installed specifically for the test (PMW-1 through PMW-11), existing monitoring wells at the site will be included in the baseline and groundwater monitoring portion of the pilot test. Monitoring wells, as follows, will be gauged and sampled accordingly throughout the pilot test:

- RW-19 Pilot test area
  - Upgradient wells: KWB-4, RW-19, MW-99, and MW-48
  - Test area wells: PMW-1, PMW-2, PWM-3, and PMW-4
  - Proximal downgradient well: PMW-5

- Downgradient wells: KWB-5 and MW-111

- MW-131 Pilot test area
  - Upgradient wells: MW-66, MW-99, MW-129, and PMW-6 (Note that only one sample at MW-99 will be collected during each sampling event, but the results will be used in the evaluation of both pilot test areas.)
  - Test area wells: PMW-7, MW-131, PMW-8, and PMW-9
  - Proximal downgradient wells: PMW-10 and PMW-11
  - Downgradient well: MW-112

The groundwater monitoring portion of the pilot test consists of conducting initial and periodic gauging of groundwater and sampling for laboratory and field parameters, as described in the following subsections. The methods described below are in accordance with the 2018 FWGWMP.

The potentiometric surface will be monitored periodically throughout the pilot test to assess potentiometric response and PSH presence/absence. The depth to PSH, if present, and groundwater will be gauged at pilot test area wells according to the schedule presented in Section 6.0. Detailed gauging procedure is described in Section 5.3 below.

Groundwater from the pilot test areas and associated wells will be analyzed, as appropriate, for the follow constituents:

- Hydrocarbon laboratory-measured parameters: BTEX, 1,2,4-trimethylbenzene, 1,3,5-trimethylbenzene, MTBE, naphthalene, GRO, and DRO;
- MNA laboratory-measured parameters: sulfate, TKN, TOC, alkalinity, ferrous iron, sulfide, and magnesium;
- MNA field-measured parameters: conductivity, ORP, DO, temperature, depth to water, and SRBs (qualitative measurement);
- Qualitative acid-producing bacteria analysis (e.g., BART Hach Tests) and qualitative sulfate-reducing bacteria analysis (e.g., BART Hach Tests); and
- Tracer laboratory-measured parameter: bromide.

Groundwater samples for laboratory analysis will be collected using low-flow sampling procedures, as described in Section 5.3. The sample parameters (depth of pump intake, pump rates, etc.) will remain consistent between sampling rounds, to the degree feasible. The low-flow sampling pump intake will be located within the target lithologic zone for each pilot test area (gravel seam near RW-19 and silty sand near MW-131) as defined by gamma logging prior to well installation. Where feasible, the sampling pump intake should also be installed at least four feet below the smear zone to avoid sampling colloids associated with partially degraded hydrocarbons in smear zones. The lowest historical groundwater elevations observed near each proposed recovery well indicate the bottom of the smear zone (pending recovery well installation logging observations) and are provided below:

- MW-131: 3338.88 feet above mean sea level (amsl) in April 2019 (21.72 feet bgs)
- RW-19: 3333.37 feet amsl in March 2019 (35.20 feet bgs)

During the first week of the pilot test, field parameters will be collected daily from each monitoring well located within each pilot test area, listed above. After one week, the field monitoring frequency will be reduced to weekly. Weekly field parameter monitoring will continue until the mixing and injection rates are optimized, which is likely within one month from the initiation of the pilot test. Conductivity measured in the field will be used as an indicator parameter – increases in conductivity will be the first indication of the amendment(s) reaching the downgradient wells.

Injection flow rates and amendment feed rates will be adjusted based on the following factors:

- Daily monitoring results. Conductivity will be measured on a daily basis using automated monitoring equipment. Groundwater samples for laboratory analysis will be collected after a 100% or more increase of conductivity has been observed in the closest downgradient well, utilizing the same sampling procedures and parameters as listed above.
- Once sulfate is detected at a concentration above 500 mg/L in all of the monitoring wells between the injection and recovery wells (initial target formation concentration or sulfate demand based on HFNR's team experience at similar site), quarterly sampling events will begin on all wells listed above. Samples will be analyzed for hydrocarbon, MNA, and tracer laboratory parameters. The target formation concentration will be refined during the pilot test based on estimated sulfate demand of the formation. Sufficient data to design the full-scale system is expected to be collected after six to 12 months of pilot system operation.
- If sulfate concentrations are below 500 mg/L in the first sampling event, sulfate dosing will be adjusted upward and wells will be resampled after an additional month; quarterly sampling will begin once sulfate concentrations in all of the monitoring wells located between the injection and recovery wells reach 500 mg/L.

5.2.8 Data Processing

Data acquired in the pilot test will be recorded and utilized to implement the full-scale system upgrade design. Data will be presented in interim progress reports to be provided to NMED and OCD on a quarterly basis. A Final Investigation Report including all data and results of the pilot test will be submitted after the completion of pilot test activities and prior to the implementation of the full-scale system upgrade.

Electronic data, including actual time, test elapsed time, and water levels, obtained by the down-hole data loggers will be downloaded into Microsoft Excel spreadsheets using software developed by the data logger vendor. The manually recorded water level and discharge/injection rate data will be manually entered into a Microsoft Excel spreadsheet.

The baseline data will be evaluated to determine if the water levels were influenced by factors other than groundwater recovery. The water level data recorded at the recovery and monitoring wells will be corrected for any outside influences such as regional water level trends, barometric pressure changes, and/or recharge effects due to precipitation.

The following hydrogeologic properties of the shallow saturated zone will be determined from each pump test and injection test: specific capacity, hydraulic conductivity (vertical and horizontal), transmissivity, coefficient of storage, and specific yield. The specific capacity determined from the injection test data will be used along with previously-determined hydrogeologic properties to determine injection rates used in the treatment efficiency portion of the pilot test. The specific capacity determined from the injection test data will be used to confirm or update previous modeling and full-scale system upgrade design criteria such as injection zone of influence, groundwater flowlines, and injection rates. The analytical results from the pilot test groundwater monitoring will be used to determine the amendment(s) and dosing to be used in the full-scale closed-loop system upgrade design.

5.3 Investigation Methods

The following sections describe detailed procedures for installation of injection and recovery wells and for groundwater monitoring. Associated quality assurance, decontamination and waste management procedures are also described. All site activities will be completed in accordance with the requirements of Appendix C of the PCC Permit and the 2018 FWGWMP, as applicable.

5.3.1 Installation of Pilot Test Injection, Recovery, and Monitoring Wells

The following general specifications apply to the injection, recovery, and monitoring wells to be installed at each of the pilot test areas, as described in Section 5.2 and shown in Figures 2a and 2b. Proposed construction diagrams for the injection, recovery, and monitoring wells are provided in Appendix B. All wells at each pilot test area will be installed using hollow stem auger (HSA) drilling methods.

For the recovery wells, the HSA will be approximately 14-inch outside diameter as was used for the Phase II recovery wells. Two 4-inch diameter casings (one for PSH recovery and one for water recovery) and a single 2-inch diameter casing (for measurement) will be installed in each recovery well borehole. Recovery well casings will be constructed of schedule 80 polyvinyl chloride (PVC). Each recovery well will be screened across the water table and target lithologic zone (gravel and silty sand) in the shallow saturated zone, with an expected screen length of 10 to 15 feet. The well screens will be constructed of 4-inch diameter, schedule 80 PVC 0.020-inch slotted screen. The filter pack will consist of either 8/12- or 10/20-grade quartz sand, depending upon the predominant shallow geology in the location where the wells are installed (i.e., either gravel or silty sand). A 2-foot sump consisting of 4-inch schedule 80 PVC will be installed beneath the well screen. For the injection wells, the HSA will be approximately 8 7/8-inch inside diameter. The well casing will be constructed of 6-inch diameter stainless steel. Each injection well will be screened at or slightly below the top of the target lithologic zone (i.e., gravel and silty sand interval), with an expected screen length of 10 feet, and will include a 2-foot sump below the screened interval. Well screen will be constructed of either type 304 stainless steel louvered shutter screen with 1/16-inch horizontal slot or V-wire wrap stainless steel with a slot size of 0.060-inch, specifically designed for injection. The filter pack will consist of either 6/9- or 8/12- grade quartz sand, depending upon the predominant shallow geology in the location where the wells are installed (i.e., either gravel or silty sand). The final filter pack size and well slot size will be based on grain size analysis of the gravel and silty sand interval.

For the monitoring wells, the HSA will be approximately 7-inch inside diameter. Monitoring well casing will be constructed of 4-inch diameter schedule 80 PVC. Each monitoring well will be screened across the water table and same target lithologic zone (i.e., gravel and silty sand interval) as the respective injection well, with an expected screen length of 10 feet. Well screen will be constructed of 0.020-inch slotted schedule 80 PVC, and the filter pack will be either 8/12- or 10/20-grade quartz sand, depending upon the predominant shallow geology in the location where the wells are installed (either gravel or silty sand).

For all types of wells, the casing and screen will be attached using threaded, flush joints. The annular space will be completed with a quartz sand filter pack to 2 feet above the top of the well screen. A 20/40-grade transition sand will extend approximately 2 feet above the filter pack sand. A 2-foot thick layer of hydrated, bentonite chips will be placed in the annular space above the transition sand. The sand filter pack and bentonite chips will be placed through the augers as they are being removed from the borehole. The sand filter pack and the bentonite chips will be poured from the top of the borehole. The remainder of the annular space to 3 feet bgs will be completed with a bentonite-cement grout placed from bottom to top using a tremie pipe and grout pump. Wells will be completed several feet above grade and will be secured with a steel protective cover placed in a 3-foot square concrete pad. An expandable watertight plug will be placed at the top of each wellhead. Four steel bollards filled with cement will be placed around each aboveground wellhead.

The drilling shall be completed under the direction of a qualified engineer or geologist who shall maintain a detailed log of the materials and conditions encountered in each boring. The following visual observations will be recorded on the boring log: lithology (color, type, grain size, sorting, etc.), moisture content (dry, damp, moist, wet), smear zone, and any field evidence of contamination (staining, odor, and photoionization detector [PID] readings). Sample information and visual observations of the cuttings and core samples shall be recorded on the boring log. Up to two soil samples from each boring will be submitted for laboratory analysis: 1) a soil sample immediately above the water table or from the bottom of the boring (if dry) and 2) a soil sample from the depth with the greatest indication of impacts from field screening (if not from the groundwater interface). Soil samples collected from locations with no historical industrial activity (i.e., within the East Field at proposed primary pilot test locations near RW-19 and MW-131) will be submitted for TPH (DRO, GRO, oil range organics [ORO] range) analysis only. Soil samples collected from locations with historical industrial activity (i.e., within the Refinery at proposed alternate pilot test locations) will be submitted for laboratory analysis of TPH (DRO, GRO, and ORO range), VOCs, and metals.

All wells will be developed to create an effective filter pack around the well screen, remove fine particles from the formation near the borehole, and assist in restoring the natural water quality of the shallow saturated zone in the vicinity of the well. Wells will be developed using surging, and bailing or pumping techniques. Each newly-constructed monitoring, recovery, and injection well will be developed until the water recovered from the well is free of visible sediment, turbidity is preferably below 10 Nephelometric Turbidity Units, and the pH, temperature, turbidity, and specific conductivity have stabilized. If the well is pumped dry during development, the water level will be allowed to sufficiently recover before the next development period is initiated. The volume of water withdrawn from each well during development will be recorded. Special attention will be paid to the development of the injection and recovery wells to ensure they meet or exceed these criteria.

Injection wells will be permitted as temporary wells that may be abandoned at the end of the pilot test; however, the injection wells will be constructed to the same specifications as permanent wells. Recovery wells will be permitted and constructed as permanent recovery wells using the same configuration as the Phase II recovery wells. Monitoring wells installed for the pilot test will be permitted as temporary wells and will likely be abandoned at the end of the pilot test. HFNR will propose to retain or abandon the wells in the Final Investigation Report (Pilot Test report). Wells will be named according to the respective existing well (RW-19 or MW-131) as shown on Figures 2a and 2b and as follows:

- Recovery wells: RW-23 (near RW-19) and RW-24 (near MW-131)

- Injection wells: IW-1 (near RW-19) and IW-2 (near MW-131)
- Monitoring wells: PMW-1 through PMW-5 (near RW-19) and PMW-6 through PMW-11 (near MW-131)

5.3.2 Groundwater Monitoring

Groundwater monitoring activities will include existing monitoring wells described above in Section 5.2.7 along with newly installed injection and recovery wells. Well locations are depicted on Figures 2a and 2b. The expected duration of groundwater monitoring activities during the pilot test is approximately 12 to 18 months or until the pilot test objectives are achieved.

5.3.3 Groundwater Gauging

The depth to PSH, if present, and groundwater will be gauged at each monitoring well prior to sampling. Prior to gauging, each well cap will be removed to allow groundwater to equilibrate with atmospheric pressure. Fluid level measurements will be collected using an oil-water interface probe to an accuracy of 0.01 feet. Measurements will be made from a marked survey datum at the top of the well casing. Data will be recorded on a paper field gauging form. The oil-water interface probe will be decontaminated before use and between wells following the procedures outlined in Section 5.3.4.

The following procedure will be used to measure the depths to PSH and groundwater:

- The probe will be lowered into the well slowly until the probe alarm sounds or light illuminates, then the tape will be raised and lowered again slowly until the alarm is again audible or the light again illuminates. The depth to fluid on the tape will be recorded to within 0.01 feet. To ensure accuracy, the measurement will be repeated.
- Well identification, date, time, depth to water, depth to PSH (if applicable), and other pertinent observations will be recorded on the field gauging form.

5.3.4 Groundwater Sampling

Groundwater will be purged and sampled from monitoring, injection, and recovery wells using low-flow methods in accordance with the NMED Hazardous Waste Bureau (HWB) Position Paper “Use of Low-Flow and Other Non-Traditional Sampling Techniques for Compliance Groundwater Monitoring” (NMED, 2001). Groundwater will be purged and sampled from irrigation wells using standard procedures described below. Data collected during the purging and sampling of each well will be recorded on a paper groundwater sampling form. Samples will only be collected in wells which areas suitable for sampling as defined by the 2018 FWGMWP (i.e., wells which contain less than 0.30 feet of PSH during gauging).

Groundwater will be purged and sampled from monitoring, injection, and recovery wells using either a peristaltic pump (for sampling depths of approximately 25 feet bgs or less) or a dedicated, stainless steel submersible pump (for sampling depth greater than 25 feet bgs). An oil-water interface probe will be lowered into the monitoring well to record the depth to water.

A multi-parameter water quality meter with flow-through cell and hand-held turbidity meter will be used during the purging process to monitor for field water quality parameters (pH, temperature, conductivity, TDS, ORP, DO, and turbidity) and demonstrate stabilization. Water quality parameters will be recorded approximately every three minutes during purging. Water quality meters used to measure field parameters will be calibrated each day according to the manufacturer's specifications. The make, model, calibration fluids, and calibration results for the water quality meters will be recorded in the field logbook. The turbidity meter test cell will be triple rinsed with groundwater from the next sample aliquot prior to each reading. The water quality parameters and depth to water will be recorded on a groundwater sampling form. A description of the water quality (e.g., turbidity, sheen, odor) will be recorded during the purging process.

The purging process will be considered complete and groundwater sampling will commence when at least four of the seven water quality parameters achieve stabilization within ten% for three consecutive readings. All seven water quality parameters will be recorded during each consecutive reading.

If the well goes dry during purging, a sample will be collected as soon after the water level recovers to a level from which a sample can be collected. The samples will be collected in clean, labeled laboratory-supplied containers prepared with the appropriate amount and type of preservative.

All sampling equipment will be decontaminated before use and between wells following the procedures outlined in Section 5.3.6. Neoprene or nitrile gloves will be worn during sample collection and while handling sample containers. New disposable gloves will be used to collect each sample. The sample containers will be labeled, secured with bubble wrap, placed in a resealable plastic bag, and immediately placed on ice in a cooler and stored below 4° Celsius. The sample labels will include the Permittee name (HFNR), site name (Artesia Refinery), unique sample identification, sample collection time and date, preservatives, and the name(s) of the sampler(s). The samples will be secured with packing material and kept below 4° Celsius with wet ice in accordance with laboratory cooler shipping guidelines. The cooler will be secured with packing tape, and a signed and dated custody seal will be placed over the cooler lid and secured with tape. The samples and a completed chain-of-custody documentation will be shipped via priority overnight delivery to the analytical laboratory. The chain-of-custody forms are to be maintained as a record of sample collection, transfer, shipment, and receipt by the laboratory. At a maximum, all samples will be submitted to the laboratory within 48 hours after collection. The laboratory will be informed that samples are being submitted for analysis and it will be confirmed that the samples were received the following day. If samples are shipped on Friday for Saturday delivery, the receiving laboratory will be contacted so provisions can be made for laboratory sample receipt.

5.3.5 Quality Assurance/Quality Control

Field quality assurance/quality control (QA/QC) samples for groundwater will be collected as follows:

- Duplicates: Collected at a frequency of ten% at the same time and from the same location as the original sample.
- Equipment blanks: Collected from non-dedicated, decontaminated equipment at a frequency of five% by pouring distilled water over the equipment and collecting the sample in the appropriate laboratory containers.
- Trip blanks: One included in each cooler shipped to the laboratory that contains samples for hydrocarbon laboratory analyses. The trip blank consists of two 40-milliliter (mL) vials of reagent water provided by the laboratory that were stored in the sample cooler at all times.

Laboratory QA/QC samples will be performed according to test methodologies specified for each analytical method. The laboratory QA/QC samples may include reagent or method blanks, surrogates, matrix spike/matrix spike duplicates, blank spike/blank spike duplicates and/or laboratory duplicates, as appropriate for each method. The laboratory QA/QC samples will be run at the frequency specified by each method.

5.3.6 Decontamination

The interface probe and other non-dedicated equipment coming into contact with groundwater will be decontaminated by the following procedures:

1. PSH, if present, will be removed with an absorbent pad.
2. Any solids will be removed to the degree possible with a brush and tap or distilled water.
3. Equipment will be washed with a brush, laboratory-grade non-phosphate detergent (e.g., Liquinox, Alconox), and potable tap or distilled water. Excess soap will be allowed to drain off the equipment when finished.
4. Equipment will be double rinsed with distilled water.

5.3.7 Investigation-Derived Waste

Investigation-derived waste (IDW) (e.g., soil cuttings, purge/development water, decontamination water) generated during well installation and monitoring activities will be collected, stored, and disposed appropriately. Soil will be contained in labeled 55-gallon drums or other suitable containers and stored on-site pending disposal. Water will be disposed of in the Refinery WWTP, upstream of the oil-water separator. Miscellaneous IDW (e.g., gloves, bailers) in contact with investigative material deemed to have no or de minimis contamination will be disposed of in a general refuse container. Any IDW deemed to have greater than de minimis contamination will be stored in labeled drums and disposed appropriately on a per case basis.

5.4 Pilot Test Monitoring and Sampling Program

A semiannual monitoring and sampling program is currently ongoing at the Refinery; descriptions of the sampling program can be found in the 2018 FWGMWP. The monitoring and sampling described here is being performed in addition to the routine monitoring activities. Data obtained in the pilot test program may be compared to historical and future routine monitoring data to determine program effectiveness and divergence (if any) from area-wide trends.

Existing and newly installed monitoring wells will be monitored at a frequency appropriate for determining injection system effectiveness. Influent COC concentrations, and influent and effluent concentrations of sulfate, TKN and field parameters will also be monitored at the amendment and reinjection system. The anticipated pilot test duration is approximately 12 to 18 months. During the treatment efficiency phase of the test, indigenous microbes that are no longer limited by late terminal electron acceptors (i.e., sulfate) will preferentially degrade adsorbed phase hydrocarbons (APH) due primarily to available proximity. These microbes use extra cellular enzymes (surfactant) to desorb the adsorbed hydrocarbons. This desorption sometimes results in a short-term increase in one or more of toluene, ethylbenzene, and xylenes (TEX) while the remaining dissolved-phase hydrocarbon constituents degrade. During the test, as microbial activity catches up with this desorption, the degradation rates of all dissolved-phase hydrocarbon constituents will equilibrate. This temporary increase in TEX concentrations is referred to as hydrocarbon desorption.

Based on existing hydraulic conductivity data available for the site, the following observations are expected during the pilot test:

- Sulfate and nitrogen concentration trends will be tracked during the pilot test and correlated with hydrocarbon constituent concentrations measured during the test. This data will then be extrapolated to determine dosing requirements for the full-scale system. These trends should be evident after three to six months of pilot test system operation;
- Hydrocarbon desorption as measured by increasing TEX concentrations and subsequent attenuation as evaluated through hydrocarbon concentration trends will be used to evaluate both dosing efficacy and PSH recovery enhancement. These trends should be observable after three to six months of pilot testing; and

- Decreasing hydrocarbon COC concentration trends will be observed after one year of pilot testing.

As appropriate with the assumptions presented above, after the pilot test injection system is installed and operating, wells will be monitored on a tiered schedule, as presented in Section 6.0. Wells will be monitored and gauged more frequently at the initiation of the pilot test and decreasing over the course of the 12-to 18-month duration of the pilot test.

5.5 Treatment Test Effectiveness

The effectiveness of the proposed treatment efficiency test will be measured primarily by comparing dissolved-phase concentrations of hydrocarbon constituents (BTEX, 1,2,4-trimethylbenzene, 1,3,5-trimethylbenzene, MTBE, naphthalene, GRO, and DRO) before and during the test (maximum 18-month period). The amendments will be considered effective if dissolved phase concentrations decrease during the test. The key dissolved-phase parameters and changes are described in Section 4.2. Table 3 provides a preliminary list of the parameters to be used in the evaluation of the pilot test. A few of the more important performance measures that will be used to holistically evaluate the effectiveness of each pilot test area are further discussed below:

- Decreasing dissolved hydrocarbon concentration trends during the test (after initial spike due to desorption of adsorbed hydrocarbons from soil matrix as described in Section 5.4). Decreasing trends will confirm the treatment is reducing dissolved hydrocarbon concentrations in situ and be used to predict the estimated timeframe to reach target concentrations with further treatment after the pilot test.
- Percent reduction of each dissolved hydrocarbon compound observed during the pilot test. Based on the HFNR team’s experience at other sites, dissolved hydrocarbons are anticipated to decrease between 50% and 90% but the degradation rate is site-specific and varies for each hydrocarbon compound. Degradation rates will be site-specific and vary for each hydrocarbon compound (benzene will generally degrade faster than xylenes, and ortho-xylenes degrade faster than meta-xylenes).
  - The percent reduction for each compound will be used with decreasing trends to predict the estimated timeframe to reach target concentrations.
  - Percent reduction will also be evaluated to determine if it varies within each pilot test area as a function of distance from the injection well.
- Number of estimated pore volume exchange cycles completed within the pilot test area compared to the predicted number of pore volume exchange cycles for the pilot test operating parameters (e.g., injection and recovery rates) and observed conditions. Based on the expected range of pilot test operating parameters, the predicted minimum

and maximum number of pore volume exchanges within each pilot test area over the 18-month pilot test are estimated to be 3.0 (injection/pumping rate of 1 gpm) and 35 (injection/pumping rate of 12 gpm). This estimate assumes the following for each pilot test area: effective area of approximately 12,000 square feet (60 feet by 200 feet), effective saturated thickness of 10 feet, and saturated porosity of 30%. This calculation will be adjusted based on the results of pump testing which will provide an estimate of the effective porosity as specific yield.

- Changes in PSH distribution, apparent thickness, and recovery rates in and around the pilot test area. However, the pilot test may not be of sufficient length to fully understand the impacts on PSH recovery. It should be noted that changes in apparent PSH thickness in wells is not a good indicator of recoverability or actual thickness of PSH in the subsurface, so the evaluation will more heavily weigh on PSH recovery data.

- Concentration trends of MNA parameters correlated with dissolved hydrocarbon concentration trends will be used to confirm/demonstrate EAB is occurring during the pilot test.

6.0 Schedule

Following approval of the work plan by NMED and OCD, and permitting through the New Mexico Office of the State Engineer (NMOSE), the proposed schedule for the pilot test is as follows:

- Week 1: Conduct baseline sampling at existing identified monitoring wells. Conduct gamma-log study of existing wells. Install soil borings to further characterize shallow geology in test areas if needed.
- Week 2: Install and develop injection and recovery wells in the two pilot test areas along with eight new monitoring wells. Develop all wells.
- Week 3: Install equipment for injection tests.
- Week 4: Conduct step-drawdown and constant-rate pump tests concurrently at the two pilot test areas.
- Week 5: Conduct injection tests concurrently at the two pilot test areas; collect groundwater quality samples.
- Weeks 6-11: Analyze injection test data and determine appropriate injection rate and dosing requirements for treatment efficiency test.
- Weeks 11-13: Install equipment for treatment efficiency test; collect baseline hydrocarbon and MNA samples; begin initial treatment with amendment(s).
- Week 14: Collect groundwater MNA field parameters daily; gauge wells daily; adjust amendment(s) and flow rate as necessary.
- Month 4: Collect groundwater MNA field parameters weekly and gauge wells weekly; adjust amendment(s) and flow rate as necessary.
- Months 5-12/18: If sulfate concentrations are greater than 500 mg/L in samples collected from the monitoring wells between the injection and recovery wells after three months, collect hydrocarbon and MNA laboratory groundwater samples and MNA field parameters quarterly. If sulfate concentrations are below 500 mg/L in the monitoring wells between the injection and recovery wells after 3 months, sulfate dosing will be adjusted upward and monthly sampling will continue until sulfate concentrations reach 500 mg/L. Gauge wells on same schedule as sampling. Adjust amendment(s) and flow rate as necessary.
- Month 15/20: Submit Final Investigation Report to NMED/OCD summarizing pilot test results, which will include the following information at a minimum:

- Description of all activities conducted throughout the pilot test, the final pilot test system layout, and any deviations to the work plan.
- Gamma logging data, including any figures and tables generated from the gamma logging results, and a discussion of the results.
- A table summarizing data ranges that define the lithology at the site based on gamma logging results and any soil boring observations, and a discussion of how the data supports the locations chosen for installation and design of the injection wells.
- Well construction and soil boring logs.
- Pump and injection test data, analysis, and a discussion of the results, including a table summarizing the equipment specifications and installation data.
- Figures depicting the locations of the pilot test wells and equipment.
- Tables summarizing field and laboratory results (including all purge parameters), water and PSH level measurements, apparent in-well PSH thicknesses, volumes of PSH recovered, groundwater extraction and injection rates, injection dosing applications, and hydrogeologic properties measured during the pilot test (see Table 3).
- Plots of COC and MNA parameter concentrations over time.
- Field data and notes.
- Summary of QA/QC data review and validation.
- Estimated pore volume exchange cycles completed compared to the predicted number of pore volume exchange cycles for the pilot test operating parameters (e.g., injection and recovery rates).
- Evaluation of pilot test system effectiveness and performance measures.
- Recommendations on the path forward for the final system upgrade.

7.0 Tables

Table 3. Parameters on which to Evaluate the Pilot Study Results (Preliminary)

Parameter	Units	Use
Concentration of COCs[1] in upgradient wells	ug/L,	Changes in concentration unrelated to the pilot study
Concentration of COCs[1] in pilot study monitoring wells	ug/L	Concentration trends; Relative concentration changes between COCs between compounds with variable degradation rates
Concentrations of COCs[1] in downgradient wells	ug/L	Change in concentration potentially related and potentially unrelated to pilot study
Influent COC[1] concentrations	ug/L	Concentration trends
Concentration of sulfate in upgradient wells	ug/L	Changes in concentration unrelated to the pilot study
Concentration of sulfate in pilot study monitoring wells	ug/L	Estimate sulfate demand; adjust sulfate amendment
Concentration of sulfate in downgradient wells	ug/L	Change in concentration potentially related and potentially unrelated to pilot study
Influent and effluent concentrations of sulfate, TKN	ug/L	Estimate sulfate and nutrient demand; used to adjust amendment
Other MNA laboratory-measured parameters – TOC, alkalinity, ferrous iron, sulfide, magnesium	mg/L or ug/L	Assess redox conditions and effect of redox conditions on water-bearing zone.
MNA Field parameters at each well: DO, ORP, pH, temperature, conductivity	DO – mg/L; ORP – millivolts; pH – S.U.; temperature – °F; conductivity – Siemens/meter	Assess redox conditions in water-bearing zone; assess degree of acidity. pH used to assess risk of creating conditions of increasing dissolved metal concentrations
Acid-generating bacteria (BART Hach Test Kit)	Qualitative indication of cfu/mL (Very High to Low)	Assess potential risk of affecting pH
Sulfate-reducing bacteria (BART Hach Test Kit)	Qualitative indication of cfu/ML (Aggressive to Non -aggressive)	Used to qualitatively assess potential presence of SRB (Note that “Non-Aggressive” can be a false negative because of the nature of the sample)

Parameter	Units	Use
Number of Pore Volumes	Number	Qualitative assessment of distribution of amendment – used in conjunction with sulfate and TKN analyses
Depth and thickness of free product – extraction well and each monitoring well	Ft	Ensure that skimmer pumps are set at proper depth and operating correctly
Groundwater elevations – each well	Ft amsl	Groundwater flow direction, groundwater drawdown, groundwater capture, potential groundwater excursions
Groundwater elevations, injection rate, and pressure at injection well	Ft amsl, gpm, psi	Used to assess correct injection and monitor for potential fouling
Volume of PSH recovered	Gallons	Document recovery volume
Specific capacity	Ft^2/day	Water-bearing zone hydrogeological characteristic
Vertical hydraulic conductivity	Ft/day	Water-bearing zone hydrogeological characteristic
Horizontal hydraulic conductivity	Ft/day	Water-bearing zone hydrogeological characteristic
Transmissivity	Ft^2/day	Water-bearing zone hydrogeological characteristic
Coefficient of storage	Unitless	Water-bearing zone hydrogeological characteristic
Specific yield	Unitless	Water-bearing zone hydrogeological characteristic

[1] Constituents of Concern (COCs): benzene, toluene, ethylbenzene, xylene (BTEX), 1,2,4-trimethylbenzene (TMB), 1,3,5-TMB, methyl tert-butyl ether (MTBE), naphthalene, gasoline range organics (GRO), and diesel range organics (DRO).

8.0 Figures

TRC
505 East Huntland Drive, Suite 250
Austin, TX 78752
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LEGEND

- Proposed Injection Well
- Proposed Monitoring Well
- Proposed Recovery Well
- Irrigation Well
- Monitoring Well
- Recovery Well
- Tanks

NOTE: PROPOSED WELL LOCATIONS ARE SUBJECT TO CHANGE BASED ON FIELD TESTING (GAMMA LOGGING, SOIL BORINGS, ETC.) AND PRESENCE OF UNDERGROUND AND ABOVEGROUND UTILITIES.

SOURCE: BASEMAP FROM GOOGLE AND THEIR DATA PARTNERS (2018).

N

0 190 380
Feet

FIGURE 2B - PROPOSED RECOVERY, INJECTION, AND MONITORING LOCATIONS NEAR MW-131

ARTESIA REFINERY - ARTESIA, NEW MEXICO
HOLLYFRONTIER NAVAJO REFINING LLC

Path: D:\Users\SRay\Desktop\GWReinjectionPilotTestWP.mxd

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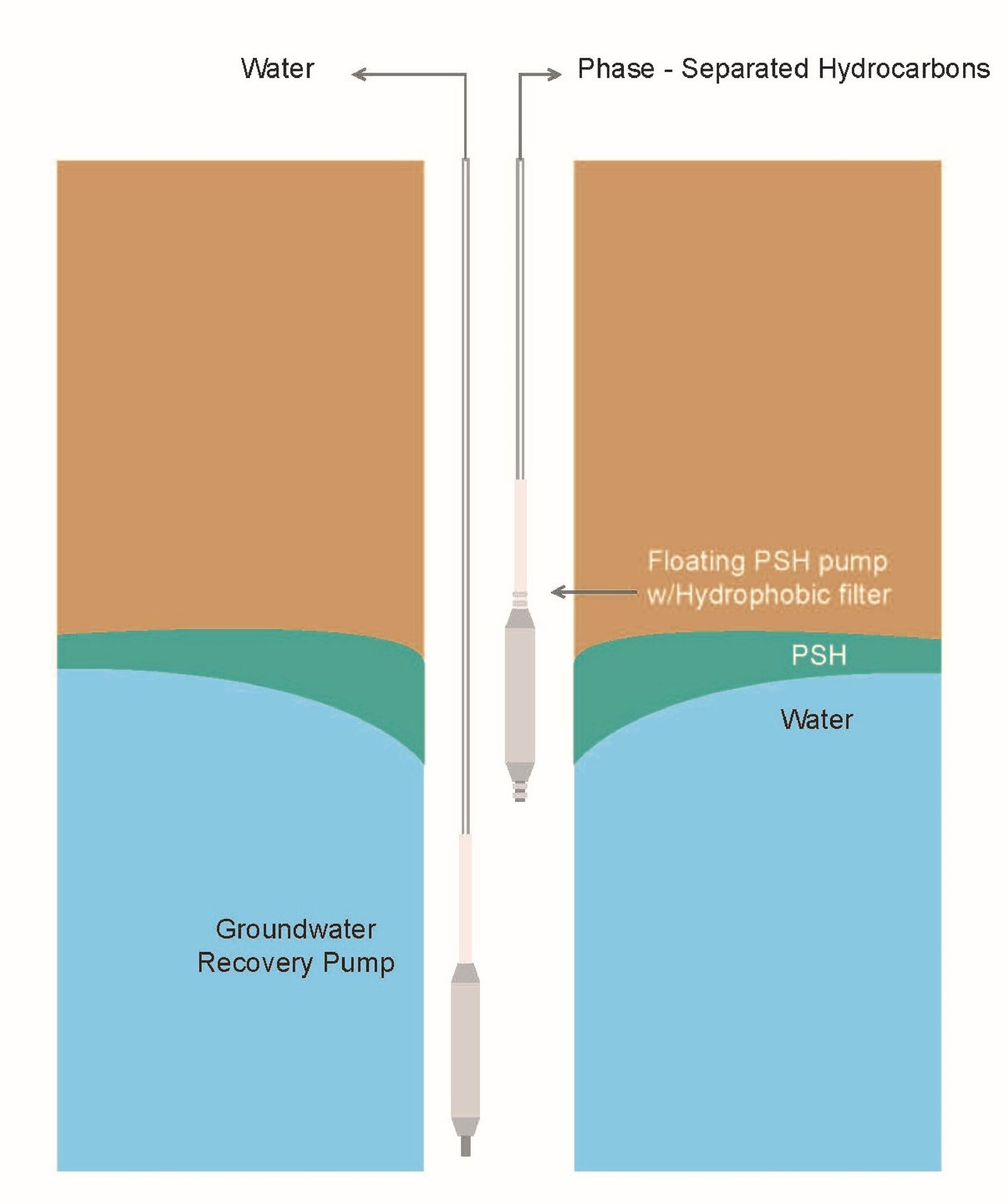

NOTE: FIGURE IS NOT TO SCALE.

FIGURE 4 - DUAL-PHASE GROUNDWATER AND PHASE-SEPARATED HYDROCARBON RECOVERY SCHEMATIC

ARTESIA REFINERY - ARTESIA, NEW MEXICO
HOLLYFRONTIER NAVAJO REFINING LLC

Path: D:\Users\SRay\Desktop\DualPhaseGW.mxd

9.0 References

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Michelle Lujan Grisham
Governor

Howie C. Morales
Lt. Governor

NEW MEXICO
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Jennifer J. Pruett
Deputy Secretary

CERTIFIED MAIL - RETURN RECEIPT REQUESTED

APR 0 6 2020

Scott M. Denton
Environmental Manager
HollyFrontier Navajo Refining LLC
P.O. Box 159
Artesia, New Mexico 88211-0159

RE: APPROVAL WITH MODIFICATIONS
REVISED GROUNDWATER AND PHASE-SEPARATED HYDROCARBON RECOVERY SYSTEM ENHANCEMENTS: REINJECTION PILOT TEST WORK PLAN, DECEMBER 2019
HOLLYFRONTIER NAVAJO REFINING LLC – ARTESIA REFINERY
EPA ID NO. NMD048918817
HWB-NRC-19-002

Dear Mr. Denton:

The New Mexico Environment Department (NMED) has completed its review of HollyFrontier Navajo Refining LLC, Artesia Refinery (the Permittee) *Revised Groundwater and Phase-Separated Hydrocarbon Recovery System Enhancements: Reinjection Pilot Test Work Plan* (Work Plan), dated December 2019. NMED hereby provides this Approval with the following modifications.

The Permittee must address all comments in this letter and submit a response letter, replacement pages, figures, and electronic version of the revised Work Plan no later than **May 29, 2020.**

This approval is based on the information presented in the document as it relates to the objectives of the work identified by NMED at the time of review. Approval of this document does not constitute agreement with all information, or every statement presented in the document.

If you have any questions regarding this letter, please contact Michiya Suzuki of my staff at (505) 476-6059.

Sincerely,

Dave Cobrain for

Kevin Pierard
Chief
Hazardous Waste Bureau

cc: D. Cobrain, NMED HWB
L. Tsinnajinnie, NMED HWB
M. Suzuki, NMED HWB
C. Chavez, EMNRD OCD
M. Holder, HFNR LLC, Dallas
R. Combs, HFNR LLC, Artesia Refinery
L. King, EPA Region 6 (6LCRRC)

File: Reading File and NRC 2020, HWB-NRC-19-002

Attachment 1

NMED Comments

Comment 1

The Permittee is reminded that NMED has expressed concerns about the effectiveness of the in situ bioremediation method chosen to conduct the Pilot Test. Nevertheless, the Pilot Test should allow for a clear demonstration of the adequacy of the remedy that will be utilized to design the full-scale system should the Pilot Test be successful.

Comment 2

The Permittee's response to NMED's Disapproval Comment 1, page 3, paragraph 1 states that "[t]he water that is reinjected will have a similar concentration of dissolved hydrocarbons as the groundwater extracted from the formation. Any reduction in dissolved hydrocarbon concentrations can only be attributable to additional in situ degradation due to increased SRB activity as confirmed by the sampling program proposed in the Work Plan." There is currently no data to support this statement. Since groundwater is extracted and reinjected, fluid movement within the aquifer matrix will change, which can cause the adsorbed contaminants to be released, mobilized, diluted, and volatilized in the vicinity of the injection and extraction wells. The aboveground operations associated with processing groundwater and mixing the amendments may cause volatilization of constituents. Furthermore, recirculation will not be a completely closed system; injection fluid will flow outside of the network and fresh groundwater will flow into the network from outside of the test cell. Unless additional data (e.g., carbon isotope analysis) is collected to support the accuracy of the statement, the Permittee cannot assume that all observed reductions in dissolved hydrocarbon concentrations is only attributable to microbial activity enhanced by the amendments. No response required.

Comment 3

The Permittee's response to NMED's Disapproval Comment 1, page 3, paragraph 2 states, "[i]f the recirculated water is treated ex-situ as suggested, it will not be compatible with the anaerobic degradation approach and, in addition, the aerated water would swiftly foul injection wells and the formation without further chemical amendment." Unless the data to evaluate the severity of fouling due to the precipitation of minerals in groundwater is provided, the viability of an aboveground groundwater treatment system must not be excluded from future consideration. Additionally, biofouling of injection wells is also likely to occur under anaerobic conditions by enhanced microbial activity. The issue associated with the precipitation of minerals may be easier to resolve in comparison to that of biofouling. No response required.

Comment 4

The Permittee's response to NMED's Disapproval Comment 4, page 4, paragraph 1 states, "[b]ased on the data, HFNR does not believe that the MTBE detected in RA-4798 can be conclusively attributed to historic refinery operations. No other dissolved volatile organic compounds (VOCs) have been detected in groundwater samples collected from RA-4798. Because MTBE is more recalcitrant and mobile than VOCs, there are numerous potential sources of MTBE upgradient of RA-4798 in addition to the Refinery that may be the source of detected concentrations." NMED does not agree with the statement that MTBE "detections cannot be attributed to historical Refinery operation based on all available data." The Permittee has not demonstrated that historical operations did not contribute to the MTBE detections or provide other possible sources for MTBE in the September 2019 *Evaluation of Methyl Tert-Butyl Ether (MTBE) in Groundwater* (September 2019 MTBE Report). The Permittee is not required to submit a response at this time. The comment can be addressed after the Permittee receives NMED's comments from the September 2019 MTBE Report.

Comment 5

The Permittee's response to NMED's Disapproval Comment 5.a. pages 5 through 6 discusses changes made to the proposed Pilot Test locations. The Permittee proposed two locations, one near RW-19 and the other at MW-131. In the response to comments letter and the revised Work Plan, the Permittee discusses how the locations will be verified as proper locations for the Pilot Test; however, the Permittee does not discuss what will happen if either location is not appropriate. During initial discussions and meetings, the Permittee also proposed another location for the Pilot Test which was west of MW-99 and north of RW-15. The location between MW-99 and RW-15 must be reserved as a contingency in case one of the two locations are not usable for the Pilot Test.

Comment 6

The Permittee's response to NMED's Disapproval Comment 5.a., page 6, paragraph 2 states that "[t]arget concentrations for the full-scale system will be based on the results of the Pilot Test but are expected to be similar to the initial target concentration of the Pilot Test. The actual amount of sulfate amendment in the full-scale system will also be adjusted based on actual conditions observed during operation of the system. The remedial timeframe may vary as it will be proportional to the mass of hydrocarbons in the targeted zone." The groundwater must meet the permit clean up standard prior to reaching Bolton Road. However, if all hydrocarbon constituent concentrations in groundwater cannot be reduced below the applicable standards while applying one pore volume of the amended groundwater during the Pilot Test, the demonstration will be considered as ineffective for full-scale implementation. Therefore, if multiple pore volumes need to be exchanged in order to reduce the concentrations below the applicable standards during the Pilot Test, the results cannot be directly interpreted to design the full-scale system. Furthermore, in order to demonstrate the comparability, the injection rate during the Pilot Test is suggested to be decreased to a lower rate than proposed to simulate the reaction time anticipated for the full-scale operations. In addition, the initial dose of amendments must be enough to satisfy the target concentrations in the formation to stimulate the SRB population and maintain microbial activity throughout operation of the full-scale system. No revision or response required.

Comment 7

The Permittee's response to NMED's Disapproval Comment 6, page 8 states "[as] described in this section of the Work Plan, an initial evaluation is to be performed prior to installation of Pilot Test wells (discussed further in Comment 7) to confirm (1) the presence of gravel through gamma logging and potentially exploratory borings and (2) confirm or adjust the location/design of the pilot test wells based on the results." Exploratory borings must be included to confirm the lithology in the area. The Permittee cannot rely on gamma logging alone, especially since there are electrical and water lines near the Pilot Test locations.

Comment 8

The Permittee's response to NMED's Disapproval Comment 7, page 8 states "[i]f the evaluation directs the placement to be different from the chosen areas, these will be noted as deviations in the Pilot Test report." NMED must also be notified, if a location is not acceptable and must be relocated.

Comment 9

The Permittee's response to NMED's Disapproval Comment 13.b., page 15 states "HFNR proposes moving the Pilot Test location near KWB-5 to near RW-19, and as such removing MW-99 from the proposed baseline groundwater monitoring program." MW-99 must remain a part of the baseline groundwater monitoring program for the reasons listed in the Permittee's response to Comment 13.b. It is important to monitor groundwater migrating from the Facility. MW-66 must also be included in the baseline groundwater monitoring program.

Comment 10

The Permittee's response to NMED's Disapproval Comment 13.c., page 15 states, "HFNR will install one additional upgradient monitoring well closer to the Pilot Test area near MW-131 (PMW-6) after completion of the baseline evaluation." According to Figure 2b (Proposed Recovery, Injection, and Monitoring Locations near MW-131), the location of proposed upgradient well PMW-6 is shown approximately 160 feet upgradient of well IW-2. The location of proposed well PMW-6 is too far from well IW-2 to observe any potential influence. The proposed well PWM-6 must be installed 100 feet or less upgradient of well IW-2 to better evaluate the effects of the injection well. Revise the applicable sections of the report and provide replacement pages and figures, as necessary.

Comment 11

The Permittee's response to NMED's Disapproval Comment 13.e, page 15 states, "[t]he objective of the Pilot Test is to demonstrate sulfate-facilitated degradation of hydrocarbons, regardless of the source of the sulfate." Sulfate levels in the vicinity of the extraction wells for the full-scale system (i.e., Bolton Road) are relatively high. If the extracted groundwater contains sulfate levels above 500 mg/L, the proposed addition of sulfate from Epsom salt may not be necessary. No revision or response required.

Comment 12

The Permittee's response to NMED's Disapproval Comment 15, page 17, paragraph 2 states that the Permittee does not agree with NMED's requirement that additional borings must be completed to provide additional support to the gamma-log study to verify the gravel seam and silty sand presence. The Permittee references geologic data in the East Field, testing for the Contaminant Migration Evaluation (CME) Report, and the boring logs as being enough information to rely on the gamma-log study. However, the Permittee states that they will consult with NMED to determine the number and location(s) of any additional soil borings after reviewing the results of the gamma logging evaluation. The results from the revised CME Report are still under review. However, based on the Permittee's conclusions, the data cannot easily be correlated to the specific lithology of the site. In the response letter, explain if the gamma-log study has similar limitations. Soil borings will be required to verify the gamma-log study.

Comment 13

The Permittee's response to NMED's Disapproval Comment 17, page 18 states, "[t]hese recovery wells have three separate well casings installed within the larger 14-inch diameter outer casing. One casing is used for groundwater recovery (4-inch diameter casing), one for PSH recovery (4-inch diameter casing), and one for instrumentation (1-inch diameter casing). The groundwater recovery pump intake will be set below the water table surface and operated to prevent intake of PSH." Accordingly, two submersible pumps are installed at different depths to extract PSH and groundwater separately. PSH will likely accumulate at the groundwater interface induced by the recovery pumps. In the response letter, explain how to ensure that the inlet of the PSH recovery pump is positioned at the interface while the inlet of the groundwater recovery pump is positioned below the PSH/groundwater interface.

Comment 14

The Permittee's response to NMED's Disapproval Comment 24, page 23 states, "[t]he pump intake depth must remain below the water surface so that air is not entrained during extraction and to prevent pump malfunction." Some pumps (e.g., pneumatic and liquid ring pumps) allow fluid recovery at the interface; therefore, the PSH recovery pump must be capable of handling dual phase fluids. No revision or response required.

Comment 15

The Permittee's response to NMED's Disapproval Comment 26, page 24 states, "[a]s described in Response 25, this target concentration [500 mg/L] was selected based on the HFNR team's experience with similar projects but will be adjusted based on estimated sulfate demand within each Pilot Test area." Since PSH is present and the PSH desorption is necessary to attenuate the PSH plume, the target concentration may need to be increased to remediate dissolved-phase constituent to concentrations below the applicable standards while applying one pore volume of the injection fluid. The Permittee must not apply more than one pore volume of the injection fluid during the pilot test to demonstrate the applicability for the full-scale system. No response required. (see also Comment 6)

Comment 16

The Permittee's response to NMED's Disapproval Comment 36, page 28, paragraph 2 states, "if the trend in concentration data is decreasing and indicates target concentrations in groundwater could be reached in a reasonable period of time beyond the timeframe of the Pilot Test, this data can still be used in design of upgrades to the full-scale system. In other words, failure to reach any predicted percent reduction may not result in the approach being deemed unsuccessful." Even if the constituent concentrations trends continue to decrease during the Pilot Test, the decline may or may not be sustained after the Pilot Test has been completed. The initial decline of constituent concentrations associated with an increased activity of sulfate reducing bacteria (SRB) may often plateau over time. Therefore, it may be difficult to fully determine if the effectiveness of the remedial design is demonstrated during the timeframe of the Pilot Test. No revision required.

Comment 17

The Permittee's response to NMED's Disapproval Comment 39, page 30, paragraph 1 states that "sulfate injected during the Pilot Test or the full-scale system will be used by the indigenous SRB to consume hydrocarbons, or if not used, captured by the downgradient recovery system and sent back "upstream". Once the goals of the system are achieved, the sulfate injections will stop, and aquifer conditions will return to aerobic conditions." It is anticipated that the injection fluid will not be completely captured by the downgradient recovery system; some amended sulfate will migrate outside of the network and will not be recovered by the injection wells. Furthermore, the aquifer at the locations affected by hydrocarbons is anaerobic and ceasing the sulfate injections would not change the aquifer's aerobic or anaerobic state. In the response letter, explain why and how the cessation of the sulfate injections "will return the aquifer to aerobic conditions."

Comment 18

The Permittee's response to NMED's Disapproval Comment 39, page 30, paragraph 2 states, "[f]ree hydrogen sulfide gas is persistent in acidic environments or in environments absent of metals to precipitate the sulfide. Groundwater in the Shallow Saturated Zone across the refinery contains dissolved metals (including iron) and is neutral as indicated by pH data collected in the field during routine semi-annual groundwater events, thus, sulfide end products will primarily be precipitated." Both acid producing bacteria and sulfate reducing bacteria thrive under reductive and nutrient-rich environments. Acidification of groundwater is often observed in the aquifer where hydrocarbon degradation is prominent. An elevated sulfide level is often observed in the aquifer where hydrocarbon degradation is occurring; however, acidification of groundwater may further dissolve metals possibly causing sulfide not to precipitate. In order to support the Permittee's statement, include qualitative acid producing bacteria analysis (e.g., BART Hach Tests) as an additional qualitative monitoring parameter. If the Permittee decides to include additional qualitative acid producing bacteria analysis, discuss the sampling frequency in the response letter and include a table summarizing the data similar to the one required for the SRB results in Comment 20.

Comment 19

In Section 5.2.5 (Treatment Efficiency Evaluation), page 25, paragraph 3, the Permittee states that "[m]agnesium and conductivity will also be used as tracers throughout the pilot test." The Permittee must collect baseline measurements for magnesium migration across the Refinery fence line, in the Pilot Test area and downgradient of the Pilot Test area prior to starting the Pilot Test.

Comment 20

In Section 5.2.7 (Groundwater Monitoring), page 27, paragraph 3, bullet item 3, the Permittee lists SRBs as a qualitative measurement during the pilot test. The Permittee did not discuss the sampling frequency for the SRBs in the revised Work Plan. Discuss the sampling frequency for the SRB qualitative measurements in the response letter. In the Pilot Test report, provide a table summarizing the SRB qualitative data to include the sample location (e.g., monitoring well, injection well, or recovery well), date sampled, time of sample (e.g., baseline, first injection, second injection, etc.), observations from samples and results, and date of result reading.

Comment 21

In Section 5.5 (Treatment Test Effectiveness), page 36, bullet item 3, the Permittee states that a "[n]umber of estimated pore volume exchange cycles completed within the pilot test area compared to the predicted number of pore volume exchange cycles for the pilot test operating parameters (e.g., injection and recovery rates) and observed conditions. Based on the expected range of pilot test operating parameters, the predicted minimum and maximum number of pore volume exchanges within each pilot test area over the 18-month pilot test are estimated to be 1.5 (injection/pumping rate of 1 gpm) and 17.5 (injection/pumping rate of 12 gpm)." In order to meet the one pore volume requirement (see Comments 6 and 15) over the 18-month Pilot Test period, the injection rate must be adjusted based on one pore volume of the estimated Pilot Test boundary. Furthermore, injecting water at a higher rate may risk physically removing (flushing) the adsorbed material, which is less likely to occur during the full-scale operation. The results from the Pilot Test would provide positively biased data for the design of the full-scale system if physical removal of hydrocarbons predominantly occurs during the Pilot Test. This may provide misleading results about the effectiveness of the in situ EAB. Revise the statement and provide replacement pages, where applicable.

Comment 22

In Section 5.5 (Treatment Test Effectiveness), page 36, bullet item 3, the Permittee states, "[t]his estimate assumes the following for each pilot test area: effective area of approximately 12,000 square feet (60 feet by 200 feet), effective saturated thickness of 20 feet, and saturated porosity of 30%." According to Appendix B (Proposed Well Construction Diagrams), the screened interval of the injection wells is proposed to be 10 feet. The effective saturated thickness within the Pilot Test boundary must be assumed to be equivalent to the length of the injection well screen (10 feet). Correct the pore volume calculation accordingly and provide replacement pages. Additionally, the effective area is assumed to be a 60-foot by 200-foot rectangle. The assumption appears to be overly simplified. The Permittee has previously provided a flow simulation model to predict flow paths for the injection fluid. It is advisable to use the same flow simulation model to predict the size of the effective area for the Pilot Test. Furthermore, a saturated porosity of 30% used for the calculation was not provided with a reference. An actual effective porosity must be used for the calculation. If the porosity value (30%) was a site-specific parameter previously determined, provide a reference in the response letter; otherwise, a site-specific value must be obtained.

Comment 23

In Section 6.0 (Schedule), page 38, bullet item 7, the Permittee describes the tables that will be a part of the deliverables for the Pilot Test report. The Permittee must also include a table of parameters used to help determine the final results of the report. The table must include units and must include the reference from previous investigation reports or studies if they are not from data collected during the investigation. The Permittee must also include a discussion about the table of parameters and provide an explanation for the values used.