

TECHNICAL MEMORANDUM

To: Nevada Environmental Response Trust

Cc: Dan Pastor, David Bohmann

From: Arul Ayyaswami

Date: August 28, 2018

Subject: Treatability/Pilot Modification No. 4 – Unit 4 Source Area In-Situ Bioremediation Treatability Study Nevada Environmental Trust Site, Henderson, Nevada

On behalf of the Nevada Environmental Response Trust (NERT, or the Trust), this technical memorandum presents Tetra Tech's recommended modification to the Unit 4 Source Area In-Situ Bioremediation Treatability Study, currently in progress at the NERT site (Site) located in Clark County, Nevada. These activities are being conducted in accordance with the approved Unit 4 Source Area In-Situ Bioremediation Treatability Study Work Plan (Work Plan) (Tetra Tech, 2018a).

Based on the initial findings of the bench-scale testing and the groundwater sampling completed to date as discussed below, Tetra Tech recommends a work scope modification to add an extended groundwater extraction test. The purpose of the extraction test is to evaluate if short-term groundwater extraction (up to three months) will reduce total dissolved solids (TDS) concentrations to levels at which bioremediation has been successful in the bench-scale testing. Details of the bench-scale testing and pre-implementation activities are described below.

1.0 BENCH-SCALE AND PRE-IMPLEMENTATION INITIAL FINDINGS

Bench-Scale Testing

Bench-scale testing is being conducted by the University of Nevada Las Vegas (UNLV) in conformance with the Unit 4 Source Area In-Situ Bioremediation Treatability Study Bench-Scale Work Plan (Tetra Tech 2017) to support the Unit 4 Source Area In-Situ Bioremediation Treatability Study design and implementation. The current bench-scale testing has shown good results for the test samples with very high TDS (approximately 20,000 mg/L) but delayed degradation for the test samples with TDS concentrations ranging from approximately 20,000 mg/L up to ultra-high TDS (approximately 50,000 mg/L). Additional microcosm studies are currently being conducted and the upper-range of TDS concentrations where biodegradation is shown to be successful may change based on those on-going tests.

Treatability Study Pre-Implementation Investigation

Pre-implementation investigation activities for the Unit 4 Source Area In-Situ Bioremediation Treatability Study were initiated in May 2018 and, as described in the approved Work Plan, included the installation of four

intermediate injection/extraction wells, four deep injection/extraction wells, one intermediate monitoring well, and one deep monitoring well within the Unit 4 basement. The baseline groundwater sample results from the newly installed wells have been incorporated into the three-dimensional visualization analysis (3DVA) model generated for the Unit 4 and 5 Buildings Investigation Comprehensive Report. Horizontal slices of the 3DVA model depicting the TDS concentration contours at 80 and 100 feet below ground surface (bgs), depths generally corresponding to the screen intervals of the newly installed intermediate and deep wells, are provided in Figures 1 and 2. TDS concentrations in groundwater samples collected from the intermediate wells range from 2,300 to 7,000 mg/L as shown on Figure 1 and summarized in **Table 1**, with the exception of U4-E-01I, where TDS concentrations in groundwater are significantly higher at 22,000 mg/L. Conversely, the TDS concentrations in groundwater samples collected at all of the deep wells located beneath the Unit 4 basement including the five recently installed deep wells and previously installed monitoring well M-251-100 are between 36,000 and 58,000 mg/L as shown on Figure 2 and summarized in **Table 1**. In comparison, the TDS concentration for the groundwater sample collected at the much deeper monitoring well M-252 is relatively low at 620 mg/L.

Table 1 TDS Concentrations in Groundwater – Wells Located in Unit 4 Basement

Well ID	Screen Interval (ft bgs)	TDS Concentration (mg/L)
Intermediate Wells		
U4-E-01I	75 - 90	22,000
U4-E-02I	75 - 90	4,800
U4-E-04I	75 - 90	4,000
U4-E-05I	75 - 90	4,900
U4-IS-MW-02I	75 - 90	7,000
M-251-60	52.3 – 62.3	2,300
Deep Wells		
U4-E-01D	95 - 110	58,000
U4-E-02D	95 - 110	41,000
U4-E-04D	95 - 110	36,000
U4-E-05D	95 - 110	42,000
U4-IS-MW-02D	95 - 110	51,000
M-251-100	92.5 – 102.5	46,000
Deeper Wells		
M-252	132.3 – 142.3	620

TDS concentrations in groundwater samples collected from monitoring wells outside of the Unit 4 basement are summarized in **Table 2**. With the exception of monitoring wells M-249-100 and M-256-100, the TDS concentrations in groundwater samples collected from monitoring wells outside of the Unit 4 basement are less than 5,000 mg/L.

Table 2 TDS Concentrations in Groundwater – Wells Located Outside Unit 4 Basement

Well ID	Screen Interval (ft bgs)	TDS Concentration (mg/L)
Shallow Wells		
M-12A	39.7 – 49.7	4,900
M-189	34.5 – 49.5	3,600
M-191	34.5 – 49.5	4,900
M-192	34.6 – 49.6	2,400
Intermediate Wells		
M-247-60	60.5 – 70.5	1,600
M-249-60	59.5 – 69.5	2,100
M-253-60	60.7 – 70.7	1,600
M-255-60	60.3 – 70.3	3,000
M-256-60	60.0 – 70.0	2,200
M-259-60	61.0 – 71.0	2,100
Deep Wells		
M-247-100	100.5 – 110.5	710
M-249-100	99.6 – 109.6	50,000
M-253-100	100.8 – 110.8	3,400
M-255-100	100.2 – 110.2	4,100
M-256-100	100.2 – 110.2	40,000
M-259-100	100.5 – 110.5	1,200
Deeper Wells		
M-241	145.0 – 150.0	550
M-248	140.4 – 150.4	600
M-250	139.4 – 149.4	620
M-254	138.4 – 148.4	560
M-257	140.4 – 150.4	590
M-258	139.9 – 149.9	550

The data presented in Figure 1 suggest that TDS concentrations in excess of 20,000 mg/L at the 80 feet bgs intermediate zone are located primarily to the northwest of the Unit 4 basement area, with only a small area of elevated concentrations present in the northwest corner of the basement. The data presented in Figure 2 indicate a larger area of TDS concentrations exceeding 20,000 mg/L in the 100 feet bgs deep zone extending to the north and west of the Unit 4 basement. As noted above, the TDS concentration isopleths presented in Figures 1 and 2 are based on the 3DVA model predictions. Due to the presence of buildings or other obstructions, there is a relative scarcity of data points to the north of the Unit 4 basement area, and the 3DVA model predictions of the extent of the TDS concentrations in that area may be less accurate. Based on the TDS concentrations indicated in the 80 feet bgs intermediate zone (Figure 1) and the very deep wells (Tables 1 and 2), the elevated TDS

concentrations present in the 100 feet bgs deep zone in the Unit 4 basement area are bounded both above and below by groundwater with lower TDS concentrations.

2.0 RECOMMENDED EXTENDED GROUNDWATER EXTRACTION TEST

Groundwater sampling in other deeper zone areas of the Site have shown groundwater perchlorate concentrations may decline fairly rapidly with pumping (Tetra Tech 2018b). Given the potentially limited vertical and horizontal extent of ultra-high TDS in groundwater underlying the Unit 4 basement, Tetra Tech suspects that similar reductions in TDS concentrations may be expected at Unit 4 under pumping conditions. Such pumping could reduce TDS concentrations in deep Unit 4 groundwater which could significantly accelerate the biodegradation process and thus provide necessary data to be evaluated in the Feasibility Study.

Standard aquifer tests used to evaluate hydrogeologic conditions, including short-term step-drawdown and constant-rate tests (a duration of up to 60 hours) have been performed on two intermediate and two deep wells in accordance with the Work Plan; however, the planned tests did not provide sufficient data regarding potential concentration reduction due to the limited test durations. The maximum groundwater extraction rates achieved during the step-drawdown and constant rate tests were:

- U4-E-01I - 3.6 gallons per minute (gpm)
- U4-E-02I - 6.2 gpm
- U4-E-01D - 0.37 gpm
- U4-E-05D - 2.25 gpm.

The extended groundwater extraction test proposed herein will be implemented over a period of up to three months to determine if groundwater extraction will reduce TDS in groundwater at the newly installed wells within the Unit 4 area to concentrations at which bioremediation has been successful in the bench-scale tests.

The extended groundwater extraction test will be performed on two newly installed injection/extraction wells, U4-E-01I and U4-E-05D, by pumping simultaneously from these intermediate and deep wells for up to three months.

Intermediate well U4-E-01I was selected for the following reasons:

- The TDS concentration in groundwater at U4-E-01I was significantly higher than the other intermediate wells.
- The results of step-drawdown test on intermediate well U4-E-01I indicated that an extraction rate of 3.6 gpm was achievable.

The deep well U4-E-05D was selected for the following reasons:

- An extraction rate of 2.25 gpm was achieved during the step-drawdown test. This is significantly higher than the extraction rate of 0.37 gpm achieved at the other deep extraction well U4-E-01D during the constant rate test.
- The TDS concentration in groundwater at U4-E-05D was in the range of the other recently installed deep wells.
- It is located in the center of the planned treatability study bioremediation area, a sufficient distance away from U4-E-01I to not influence the pumping of U4-E-01I, and relatively close to the 3DVA predicted 20,000 mg/L TDS isopleth.

The extended groundwater extraction test will utilize the following key components:

- Submersible pumps will be installed in each well and extracted groundwater will be routed to a temporary accumulation container(s) (e.g. 21,000-gallon frac tank or similar) staged within secondary containment;
- Each wellhead will have individual piping with a sample port, flowmeter, pressure gauge, a flow control valve and a check valve;

- Individual piping from each well will connect to a common header pipe for connection to the temporary container(s);
- The temporary container(s) will have a high and a high-high float switch and leak sensor in the secondary containment; and
- The float switches and leak sensor will be connected to a relay to turn off power to the pumps, if activated.

The extracted groundwater will be temporarily stored in the accumulation container(s) prior to transfer to the GW-11 Pond on-site or transport off-site for disposal.

Flow rates will be monitored throughout the extended groundwater extraction test. All flow rate changes and interruptions will be recorded, and the causes for such changes will be noted, if known. Electronic pressure transducer/data logger units will be used to record groundwater level changes over time in the nearby extraction and monitoring wells.

Groundwater samples will be collected at the two extraction wells (U4-E-01I and U4-E-05D) and five monitoring wells (U4-E-01D, U4-IS-MW-02I, U4-IS-MW-02D, U4-E-02I, and U4-E-04D) to evaluate the change in groundwater concentrations over time. The proposed groundwater performance sampling program is provided in **Table 3**. The groundwater samples will be sent off-site to a certified analytical laboratory to be analyzed for TDS and chemicals of potential concern (COPCs) relevant to the in-situ biodegradation pathway (perchlorate, chlorate, nitrate, chromium and hexavalent chromium). Tetra Tech will evaluate the data each month to determine if the results from the analytical laboratory indicate that TDS concentrations in the extracted groundwater have reduced to the target range, or if adequate data is available to forecast the extraction duration necessary to achieve the target range. The groundwater analytical data is intended for evaluating potential declining TDS and concentrations of COPC during the groundwater extraction test and is not part of the analytical testing planned to evaluate the effectiveness of the in-situ bioremediation treatment; however, the groundwater analytical data will be validated at Level 2A in accordance with the Work Plan.

Table 3 Performance Monitoring Sampling Protocol

Parameter	Analytical Method	Day						Week							
		0	1	3	5	7	12	3	4	5	6	7	8	10	12
Extraction Wells (U4-E-01I and U4-E-05D)															
Field Parameters/Sampling															
pH	Field Meter	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Temperature	Field Meter	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Laboratory Analyses															
Hexavalent Chromium	SW7199	X				X			X				X		X
Total Chromium	SW-6010B or 6020	X				X			X				X		X
Chlorate	E300.1/SW9056	X				X			X				X		X
Nitrate	E300/SW9056	X				X			X				X		X
TDS ¹	E160.1	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Chloroform	SW-8260B	X				X			X				X		X

Parameter	Analytical Method	Day						Week							
		0	1	3	5	7	12	3	4	5	6	7	8	10	12
Extraction Wells (U4-E-01I and U4-E-05D)															
Perchlorate	E314	X				X			X				X		X
Observation Wells (U4-E-01D, U4-IS-MW-02I, U4-E-02I, U4-IS-MW-02D, U4-E-04D)															
Field Parameters															
pH	Field Meter	X				X			X				X		X
ORP	Field Meter	X				X			X				X		X
DO	Field Meter	X				X			X				X		X
Conductivity	Field Meter	X				X			X				X		X
Temperature	Field Meter	X				X			X				X		X
Laboratory Analyses															
Hexavalent Chromium	SW7199	X				X			X				X		X
Total Chromium	SW-6010B or 6020	X				X			X				X		X
Chlorate	E300.1/SW9056	X				X			X				X		X
Nitrate	E300/SW9056	X				X			X				X		X
TDS	E160.1	X				X			X				X		X
Chloroform	SW-8260B	X				X			X				X		X
Perchlorate	E314	X				X			X				X		X
Notes:															
1. The turnaround time on the laboratory analysis for TDS on the effluent from the extraction wells will be 48-hours.															

Tetra Tech anticipates that the extended groundwater extraction tests will continue for a maximum period of three months to observe the decline in TDS concentrations. If the TDS concentrations in groundwater decline at U4-E-01I to less than 20,000 mg/L prior to three months, Tetra Tech will confer with the Trust on whether to continue to the extended pumping test at U4-E-01I or to transfer the extraction pump from U4-E-01I to U4-E-01D to evaluate TDS concentration decline at the well with the highest TDS concentration in groundwater.

The data obtained from the extended groundwater extraction test will be used for groundwater modeling and for preparing the final treatability study design to be included in the Work Plan Addendum. Specifically, the data will be used to evaluate the long term sustainable pumping rates, concentration trends, the hydraulic influence between the intermediate and deep zones, well configuration, and sequence of injection and extraction system operation. In addition, the groundwater flow data obtained during the extended groundwater extraction tests will be useful for confirming design parameters for the water conveyance pipeline planned as part of the Treatability Study; and the flow and chromium concentration data will be used to evaluate the existing chromium treatment plant's capacity to treat the water delivered from the Unit 4 area.

3.0 REFERENCES

Tetra Tech, Inc. (2017). *Unit 4 Source Area In-Situ Bioremediation Treatability Study Bench-Scale Work Plan, Nevada Environmental Response Trust Site, Henderson, Nevada*. September 12, 2017.

Tetra Tech, Inc. (2018a). *Unit 4 Source Area In-Situ Bioremediation Treatability Study Work Plan, Nevada Environmental Response Trust Site, Henderson, Nevada*. February 5, 2018.

Tetra Tech, Inc. (2018b)*. *Vacuum Enhanced Recovery Treatability Study Results Report, Nevada Environmental Response Trust Site, Henderson, Nevada*. July 12, 2018.

*Currently under NDEP Review

CERTIFICATION

I hereby certify that I am responsible for the services described in this document and for the preparation of this document. The services described in this document have been prepared in a manner consistent with the current standards of the profession, and to the best of my knowledge, comply with all applicable federal, state, and local statutes, regulations, and ordinances. I hereby certify that all laboratory analytical data was generated by a laboratory certified by the NDEP for each constituent and media presented herein.

Description of Services Provided: Prepared Treatability/Pilot Modification No. 4 – Unit 4 Source Area In-Situ Bioremediation Treatability Study



Kyle Hansen, CEM
Field Operations Manager/Geologist
Tetra Tech, Inc.

August 28, 2018

Date

Nevada CEM Certificate Number: 2167
Nevada CEM Expiration Date: September 18, 2020

CERTIFICATION

Treatability/Pilot Modification No. 4 – Unit 4 Source Area In-Situ Bioremediation Treatability Study

**Nevada Environmental Response Trust Site
(Former Tronox LLC Site)
Henderson, Nevada**

Nevada Environmental Response Trust (NERT) Representative Certification

I certify that this document and all attachments submitted to the Division were prepared at the request of, or under the direction or supervision of NERT. Based on my own involvement and/or my inquiry of the person or persons who manage the systems(s) or those directly responsible for gathering the information or preparing the document, or the immediate supervisor of such person(s), the information submitted and provided herein is, to the best of my knowledge and belief, true, accurate, and complete in all material respects.

Office of the Nevada Environmental Response Trust

Le Petomane XXVII, not individually, but solely in its representative capacity as the Nevada Environmental Response Trust Trustee

not individually but solely as President
Signature: Jay A. Steinberg, not individually, but solely in his representative capacity as President of the Nevada Environmental Response Trust Trustee

Name: Jay A. Steinberg, not individually, but solely in his representative capacity as President of the Nevada Environmental Response Trust Trustee

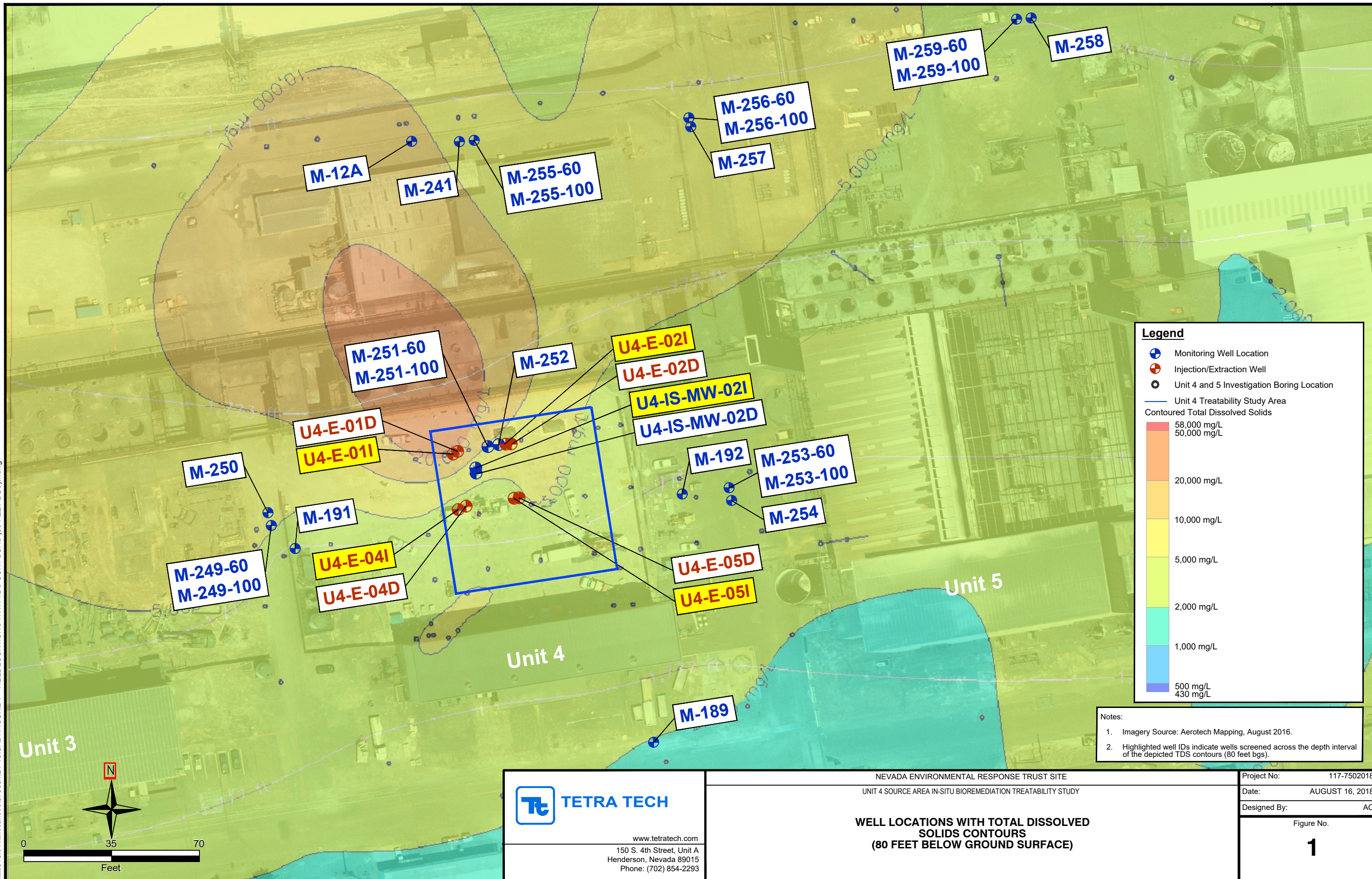
Title: Solely as President and not individually

Company: Le Petomane XXVII, Inc., not individually, but solely in its representative capacity as the Nevada Environmental Response Trust Trustee

Date: 8/27/18

Figures

\\fs318fs11.tl.local\ces\87600M21-18\CAD\FIGURE 1 - WELL LOCATIONS WITH TDS CONTOURS (80 FEET BGS).r.dwg



Legend

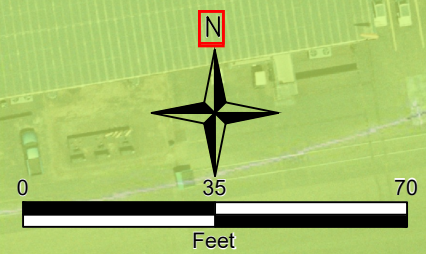
- Monitoring Well Location
- Injection/Extraction Well
- Unit 4 and 5 Investigation Boring Location
- Unit 4 Treatability Study Area

Contoured Total Dissolved Solids

- 58,000 mg/L
- 50,000 mg/L
- 20,000 mg/L
- 10,000 mg/L
- 5,000 mg/L
- 2,000 mg/L
- 1,000 mg/L
- 500 mg/L
- 430 mg/L

Notes:

- Imagery Source: Aerotech Mapping, August 2016.
- Highlighted well IDs indicate wells screened across the depth interval of the depicted TDS contours (80 feet bgs).



TETRA TECH

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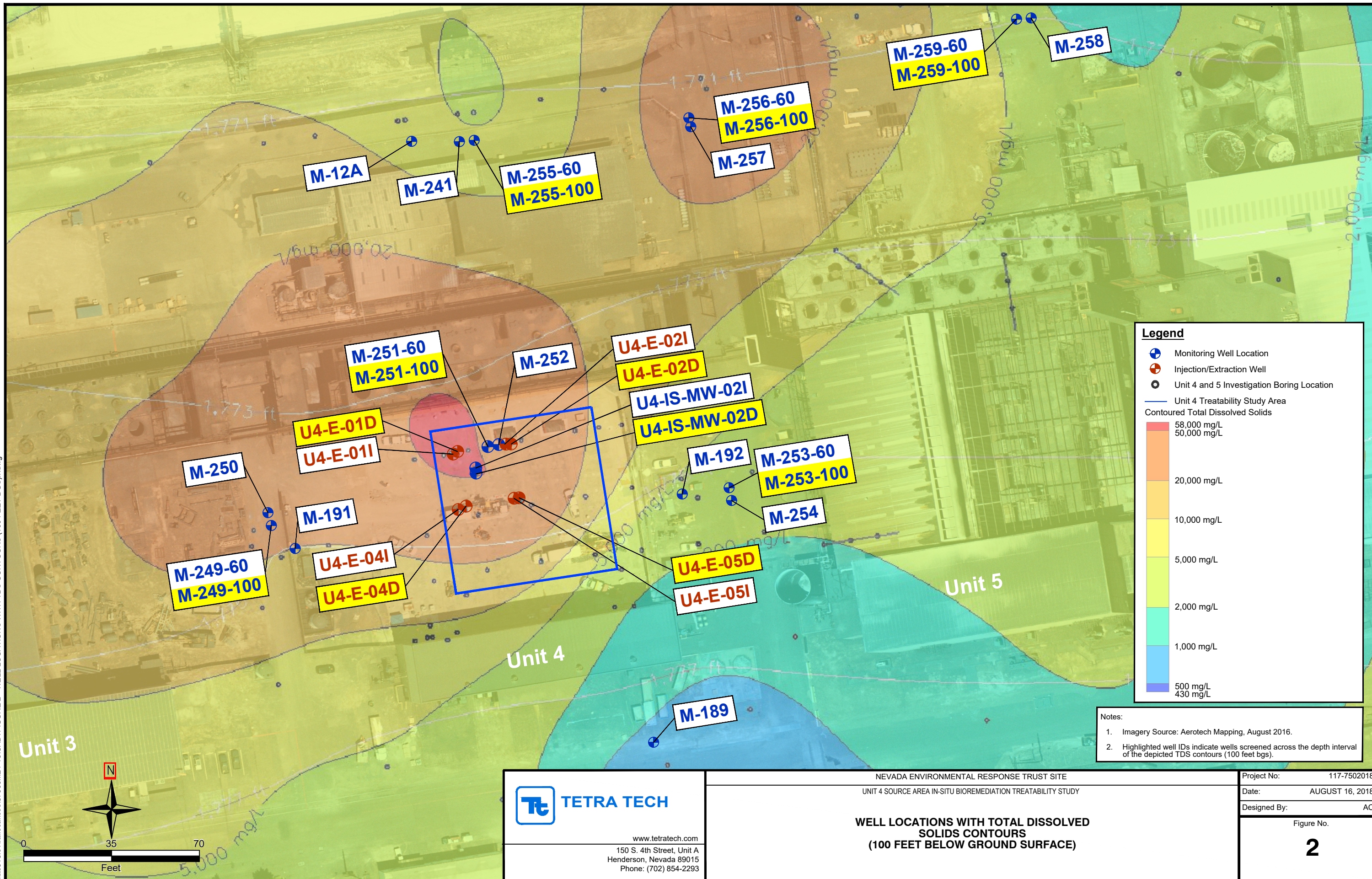
NEVADA ENVIRONMENTAL RESPONSE TRUST SITE
 UNIT 4 SOURCE AREA IN-SITU BIOREMEDIATION TREATABILITY STUDY

WELL LOCATIONS WITH TOTAL DISSOLVED SOLIDS CONTOURS (80 FEET BELOW GROUND SURFACE)

Project No: 117-7502018
 Date: AUGUST 16, 2018
 Designed By: AC

Figure No.
1

\\fs318fs11.tl.local\ces\87600\21-18\CAD\FIGURE 2 - WELL LOCATIONS WITH TDS CONTOURS (100 FEET BGS).r.dwg



Legend

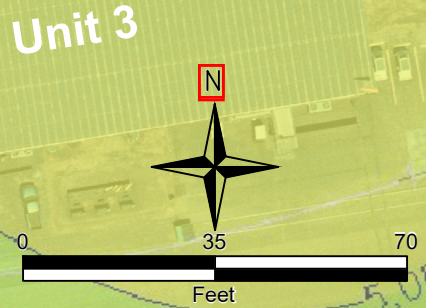
- Monitoring Well Location
- Injection/Extraction Well
- Unit 4 and 5 Investigation Boring Location
- Unit 4 Treatability Study Area

Contoured Total Dissolved Solids

- 58,000 mg/L
- 50,000 mg/L
- 20,000 mg/L
- 10,000 mg/L
- 5,000 mg/L
- 2,000 mg/L
- 1,000 mg/L
- 500 mg/L
- 430 mg/L

Notes:

1. Imagery Source: Aerotech Mapping, August 2016.
2. Highlighted well IDs indicate wells screened across the depth interval of the depicted TDS contours (100 feet bgs).



TETRA TECH

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NEVADA ENVIRONMENTAL RESPONSE TRUST SITE
 UNIT 4 SOURCE AREA IN-SITU BIOREMEDIATION TREATABILITY STUDY

WELL LOCATIONS WITH TOTAL DISSOLVED SOLIDS CONTOURS (100 FEET BELOW GROUND SURFACE)

Project No: 117-7502018
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Figure No.
2