Baseline Groundwater Quality at Owens Lake

Eastern Sierra Environmental and Water Rights Group

Water Operations Division

Los Angeles Department of Water and Power

June 2020

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Executive Summary

The Los Angeles Department of Water and Power (LADWP) is implementing the Owens Lake Groundwater Development Program (OLGDP). To ensure that groundwater-dependent resources in and around Owens Lake are protected, LADWP is working with stakeholders in Owens Valley to develop Resource Protection Protocols (RPPs) for each category of groundwater-dependent resources. Protection of groundwater quality in non-LADWP wells is a component of RPP, which includes establishing a baseline for groundwater quality in and around Owens Lake.

LADWP collected water quality samples from over 100 wells and springs at Owens Lake in 2019 to measure the concentration of indicator constituents in the groundwater and establish a baseline water quality. Temperature, pH, and electrical conductivities were measured in the field, and samples were collected to analyze for concentrations of total dissolved solids, arsenic, boron, fluoride, and uranium in the laboratory.

Results of the sampling exhibit water quality variations based on location and depth with the exception of a few outliers. In the shallow wells, water quality is relatively lower along the eastern and southern shores of Owens Lake and higher along the northern and western shores. Wells located off the lakebed and on alluvial fans have higher water quality than those on the lakebed due to mountain front recharge they receive. Water quality generally improves in the deeper wells.

As a component of OLGDP, this report establishes a baseline for the groundwater quality at Owens Lake. When the proposed groundwater pumping for dust mitigation at Owens Lake occurs, data presented in this report will help quantify the effects of groundwater pumping on water quality by comparing pre-pumping and during pumping.

1. Purpose

The Los Angeles Department of Water and Power (LADWP) is developing Resource Protection Protocols (RPPs) for groundwater-dependent resources as part of Owens Lake Groundwater Development Program (OLGDP). The purpose this report is to establish a water quality baseline at Owens Lake to ensure protection of water quality in non-LADWP wells. The scope of work for the 2019 water quality sampling included all accessible groundwater sampling locations on Owens Lake and the immediate surrounding areas.

2. Background

2.1 Dust Emissions at Owens Lake

Owens Lake, the terminus of Owens River, is a dry lake located approximately five miles south of Lone Pine in Inyo County. During wind events, Owens Lake emits dust particles into the atmosphere, acting as a source of air pollution. LADWP started mitigating dust on Owens Lake in 2000, primarily using water diverted from the Los Angeles Aqueduct. LADWP conducted an evaluation of the feasibility of using water from underneath Owens Lake (Owens Lake Groundwater Evaluation Project [OLGEP]) between 2009 and 2012 to mitigate dust emissions. The OLGEP concluded that the use of groundwater for dust mitigation is feasible depending on an improved understanding of the hydrogeology of Owens Lake. Based on the findings of OLGEP, LADWP started implementing OLGDP in 2014 and as part of that to establish a baseline of the groundwater quality.

2.2 Geology of Owens Lake and Effects on Groundwater Quality

As the most western basin of the Basin and Range Province, bounded by Eastern Sierra Mountains and Inyo Mountains, the geology of Owens Lake and its effects on groundwater varies throughout the area. Numerous mapped Quaternary fault traces and surveyed ancient faults shape the subsurface stratigraphy of the lake, the most prominent being the Owens Valley Fault on the west side of the lake with at least 6,000 feet of vertical displacement, the Owens River Fault located in the center of the lake, and the Inyo Mountains Fault along the east which offset the valley fill up to 7,000 feet. The Owens basin consists primarily of fluvial and lacustrine deposits derived from the chiefly granitoid Sierra Nevada and White-Inyo Mountains with interstratified volcanic deposits and alluvial fan deposits (Pretti, 2002). The primary control of the chemistry of water in the basin is due to lithology (Lopes, 1987). The deposition of coarse-grained materials (sand and gravel) is attributed to runoff from streams at relatively high velocities. This phenomenon, due to the slopes of mountainsides, allows coarse-grained materials to remain in streams until energy dissipates, forming alluvial fan sedimentation around the perimeter of Owens Lake as the result of drainage basin erosion (Lopes, 1987).

Due to the presence of coarse-grained soils, wells on alluvial fans receive high recharge from the nearby mountains. Below the surficial aquifer, an aquitard consisting of mainly impermeable soil separates the main active aquifers below (Figure 1). Below the surficial layer, several aquifers are formed by the presence of permeable soils.

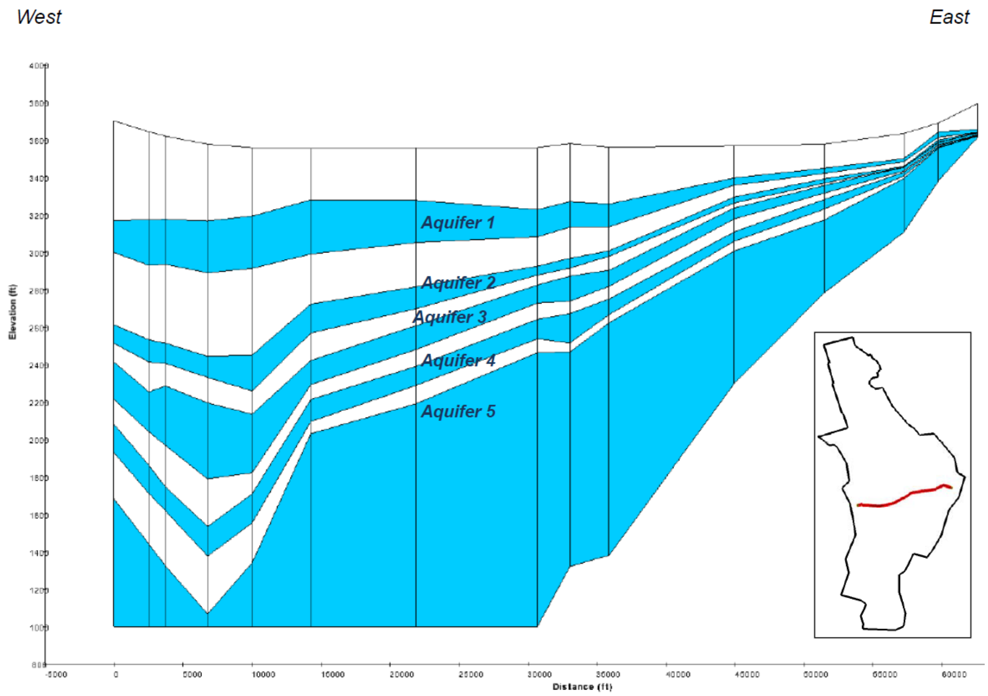

Figure 1: Cross-section Owens Lake aquifers from the East to West (MWH, 2012)

Owens Lake is a terminal lake with outflows by evapotranspiration from springs, seeps, and flowing wells, and evaporation from the lakebed surface and particularly the brine pool. As a result of surface evaporation, dissolved solids accumulate on the surface of the lake, which includes constituents of concern to this study.

2.3 Great Basin Unified Air Pollution Control District (GBUAPCD) Study

Prior to LADWP's groundwater monitoring efforts, GBUAPCD conducted an evaluation of shallow groundwater hydrology and water quality, based on hydrology and chemistry monitoring data, from 1998 to 2004 (GBUAPCD, 2009). The GBUAPCD measured parameters from systematic monitoring including depth-to-water, flow rate, and salinity (based on electrical conductivity). Other parameters, including pH, temperature, dissolved oxygen concentration, and hydrogen sulfide concentration, were also monitored. GBUAPCD analyzed chemical compositions in detail. Electrical conductivity measurements provided a general indication of groundwater constituent concentrations at Owens Lake (Figure 2). The data collected by GBUAPCD overlaps with that collected during LADWP's 2019 groundwater quality sampling.

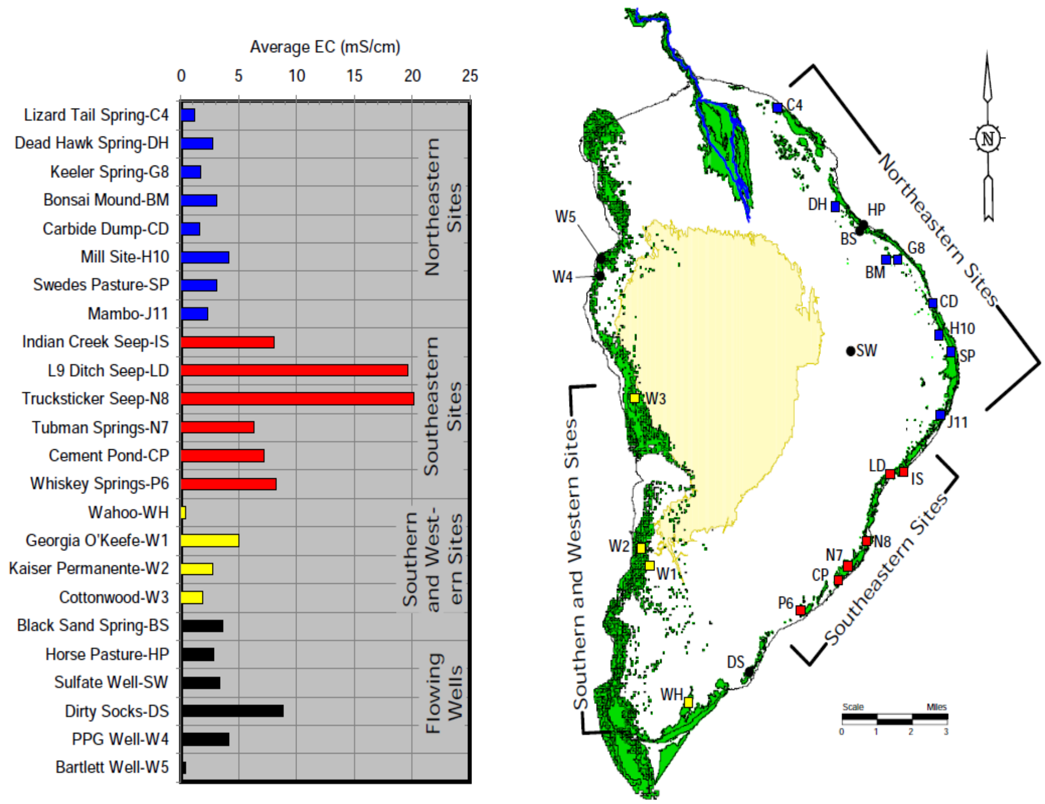

Figure 2: A map and chart produced by GBUAPCD, showing shallow well locations at Owens Lake along with their respective electrical conductivity (GBAPUCD, 2009)

2.4 Previous LADWP Water Quality Sampling

Water quality sampling is LADWP's standard practice after constructing and developing new wells. As such, samplings have been conducted at cluster wells (2011), alluvial fan wells (2014), and piezometers (2016) drilled in and around the Owens Lake. In addition, an initial baseline water quality sampling was conducted at 14 key wells, representing 10 identified non-LADWP well "clusters" to protect water quality of non-LADWP wells in 2017 (Table 1 and Figure 3). Groundwater samples were collected and analyzed by LADWP per California Title 22 Code of Drinking Water Standards to delineate the baseline quality of groundwater throughout Owens Lake.

During the LADWP's 2017 sampling event, non-LADWP wells were grouped geographically into "clusters" and key wells were selected as a representative for the cluster. Monitoring every non-LADWP well in the area is not practical or necessary; therefore, select wells were chosen for water level monitoring and water quality sampling that represented the entire group of wells. Clusters were grouped based on wells in similar geographic and/or hydrologic areas (MWH ES-1).

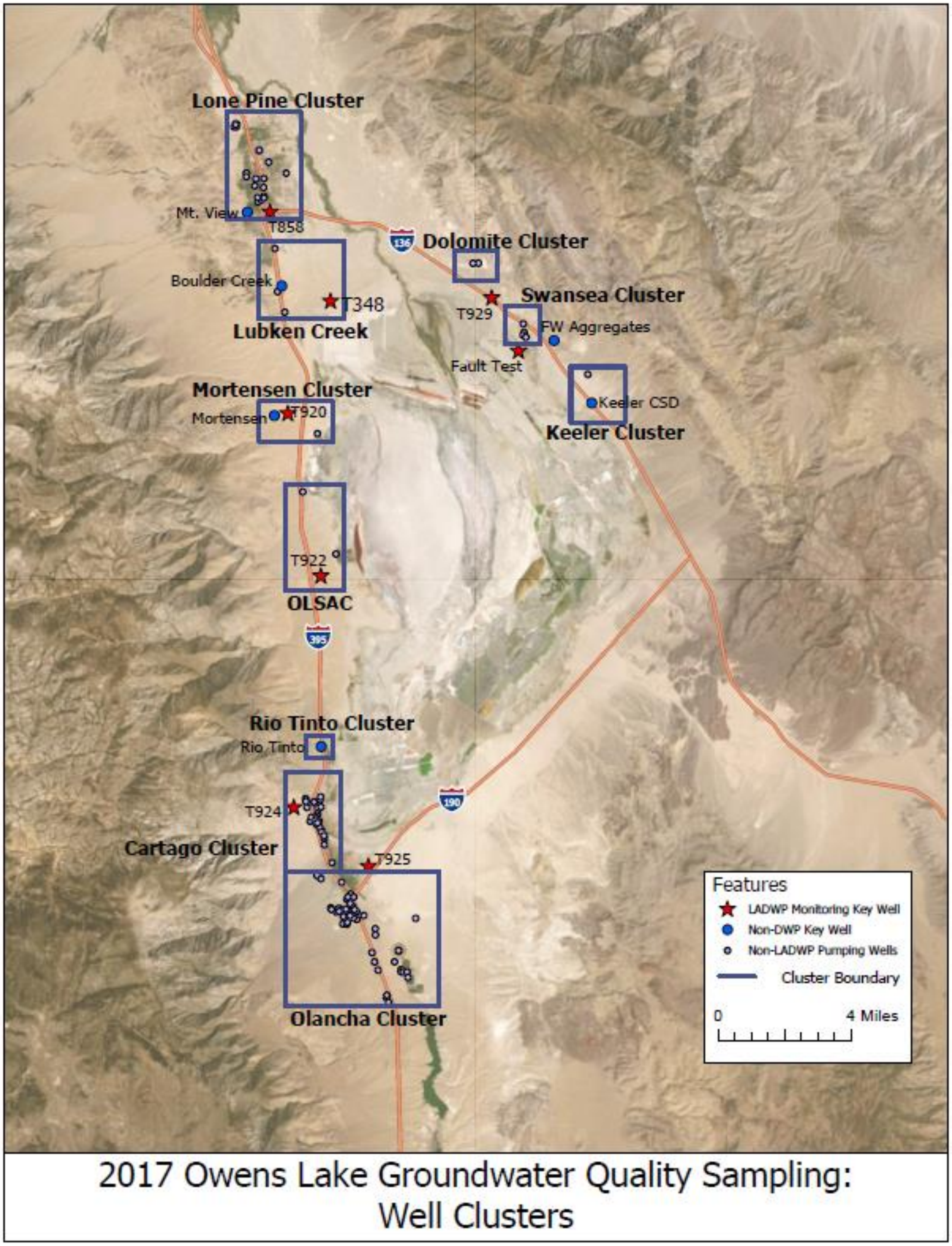

Figure 3: Map showing non-LADWP well clusters and representative wells

2.5 Groundwater Indicator Constituents

Using results of the 2017 baseline sampling, LADWP identified indicator constituents, along with trigger levels and management actions, for 2019 sampling. The 2019 sampling efforts included all available wells at Owens Lake, in addition to the 10 representative wells initially sampled. Indicator constituents included: arsenic, boron, fluoride, total uranium, and total dissolved solids (TDS). Since most of the non-LADWP wells are planned to be protected as a potable water supply, indicator constituent concentrations were compared with MCL, CA-NL, SMCL. These constituents were selected based on observations that their concentrations either exceeded or have the potential to exceed (in wake of degrading water quality) a maximum contaminant level (MCL), secondary maximum contaminant level (SMCL), or California state notification level (CA-NL). Arsenic and boron were chosen due to their known presences at Owens Lake. Fluoride and total uranium were selected due to their detections during the 2017 baseline sampling period. TDS was selected to monitor groundwater salinity levels, similar to the GBUAPCD study. Comparisons of the results of all groundwater indicator constituents, except TDS, are presented in Appendix A. Some wells had non-detectable (ND) amounts, effectively concentrations of zero, of indicator constituents.

2.5.1 Total Dissolved Solids (TDS)

TDS is a measure of all dissolved organic and inorganic substances, along with any micro-granular suspended particles able to pass through filtration. TDS is not a toxic contaminant itself, but provides an overall indication of salinity levels in groundwater. TDS does not have a primary MCL, but rather a level SMCL used to control aesthetic characteristics of water. According to the United States Environmental Protection Agency (EPA), the SMCL for TDS is 500 mg/L (EPA, 2020). TDS concentrations of all groundwater samples are presented in Figure 3 (bar sizes are relative, ranging from 79 mg/L to 86,100 mg/l).

2.5.2 Arsenic

Arsenic is a naturally occurring element found in air, rocks, soil, and water. It is also found in groundwater underneath some areas of Owens Lake. The MCL for arsenic is 0.010 mg/L in drinking water (SWRCB, 2019). Concentrations of arsenic across all sampling sites, in comparison to one another, are presented in Figure A.1 of Appendix A (bar sizes are relative, ranging from non-detectable to 17.5 mg/L).

2.5.3 Boron

Boron is a naturally occurring element found within earth’s crust. Soil and rocks containing boron compounds eventually leach the substance into groundwater. As a chemical compound, boron is unregulated with no established MCL. However, California has a notification level of 1 mg/L that requires an appropriate response (SWRCB, 2017). Concentrations of boron across all sampling sites, in comparison to one another, are presented in Figure A.2 of Appendix A (bar sizes are relative, based on a range from non-detectable to 326 mg/L).

2.5.4 Fluoride

In the United States most public drinking water systems undergo fluoridation, the adjustment of fluoride to reduce tooth decay. Fluoride is an ionic compound of fluorine found in rocks, and thus can be concentrated in groundwater. The EPA has set the SMCL of fluoride at 2.0 mg/L (SWRCB, 2019). Concentrations of fluoride across all sampling sites, in comparison to one another, are presented in Figure A.3 of Appendix A (bar sizes are relative, based on a range from non-detectable to 231mg/L).

2.5.5 Total Uranium

Water containing high levels of uranium is unsuitable for human consumption and very toxic. The EPA has set the MCL as 0.03 mg/L for total uranium in drinking water (EPA, 2020). Concentrations of uranium across all sampling sites, in comparison to one another, are presented in Figure A.4 of Appendix A (bar sizes are relative, based on a range from non-detectable to 0.685 mg/L).

Table 1: LADWP Owens Lake groundwater quality sampling of cluster areas in 2017

Well Name	Cluster Name	Arsenic (mg/L)	Boron (mg/L)	Fluoride (mg/L)	Uranium (mg/L)	TDS (mg/L)
Mt. View Trailer	Lone Pine	0.002				79
T858	Lone Pine	0.001	0.192	0.24	0.01139	292
FW Aggregates	Dolomite	**0.045**	**2.8**	1.2	ND	810
T929	Dolomite	0.0014	**1.53**	1.21	0.00034	680
Fault Test Well	Swansea	**0.0157**	**11.1**	1.39	0.00201	**1,630**
Keeler CSD	Keeler	**0.0770**	**2.5**	1.2	ND	820
T925	Olancha	0.0024	0.137	0.34	0.00034	188
T924	Cartago	0.0034	0.089	**2.14**	**0.03176**	246
Rio Tinto	Rio Tinto	0.0044	0.141	0.99	0.00034	153
T922	OLSAC	0.001	0.051	0.1	0.00061	129
Grace Mortensen	Mortensen	**0.0416**	0.152	0.97	0.01152	392
T920	Mortensen	0.0066	0.05	0.37	0.00087	120
Boulder Creek RV	Lubken	0.0038	**1.09**	1.82	0.02211	421
T348	Lubken	0.001	**3.84**	**3.42**	0.00034	**1,360**

**The concentrations bolded above in Table 1 indicate the wells that had concentration levels higher than the MCLs for arsenic, fluoride, and uranium, or the CA-NL and sMCL for boron and TDS, respectively.*

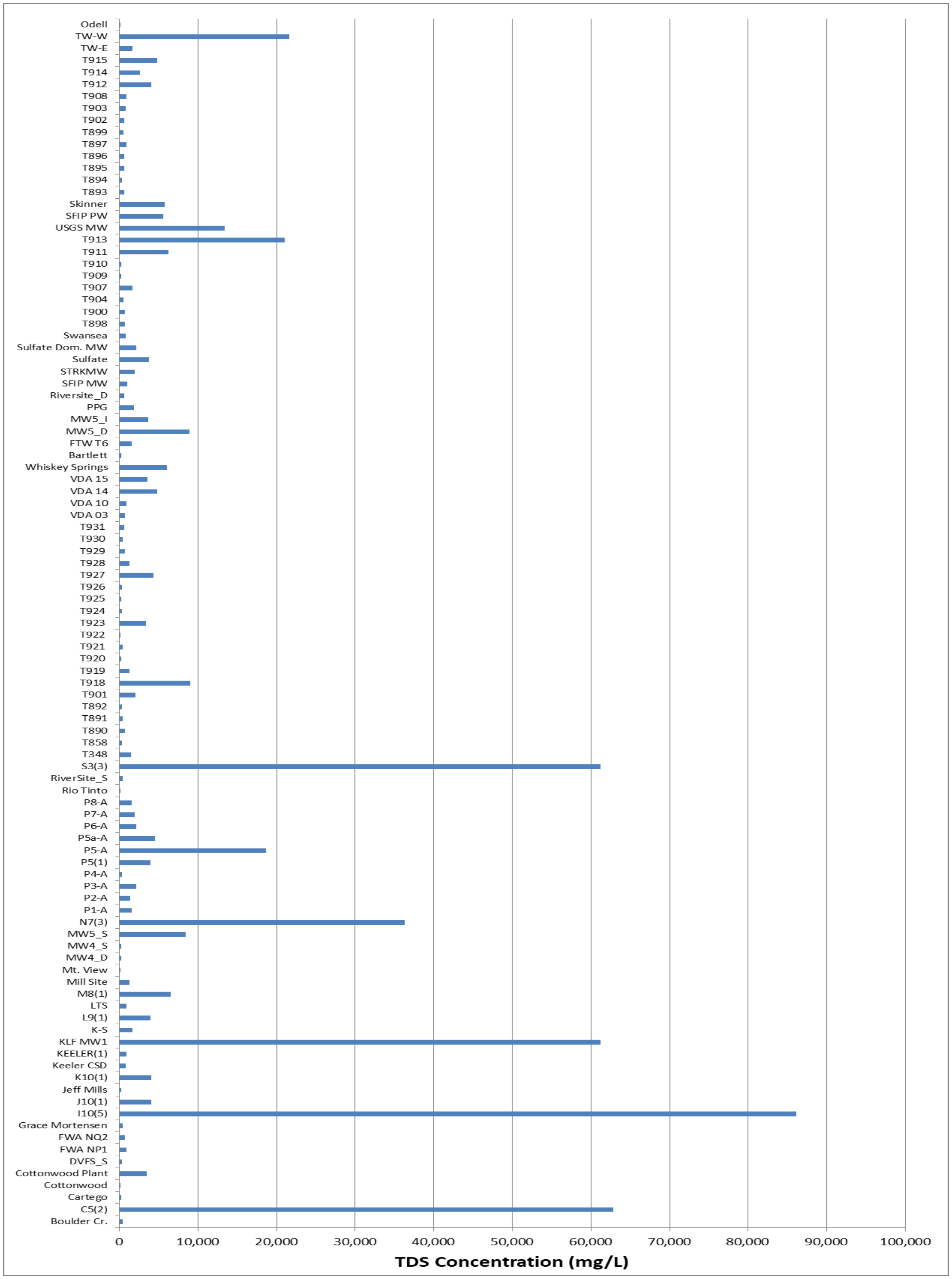

Figure 4: Total dissolved solids concentrations in all water samples

2.6 Field Parameters Measurement During Sampling

In addition to laboratory testing for the indicator constituents, field parameters were measured at the time of sampling to ensure that samples were representative. Field parameters include specific conductivity, pH, and temperature. A list of all measured field parameters is presented in Table C.2 in Appendix C.

3. Methodology

Prior to sampling, each well was purged of standing groundwater in its well column. Purging a well of three well casing volumes is typically considered sufficient to obtain a representative sample (USOSMRE, 2012). Field parameters were intermittently measured during purging. Once the parameters stabilized, the well was considered adequately purged and ready for sample. In the event that after purging recharged water inside the casing was insufficient to collect a sample, wells were allowed to recharge overnight. Sampling flowing wells and springs didn't require purging due to the continuous flow of groundwater to surface.

Representative samples were collected in bottles labeled per constituent. Hydrochloric acid was added to some bottles to preserve the sample for the testing of metals. Samples were packed into ice-filled coolers and transported to LADWP's water quality laboratory for analysis.

Efforts were made to contact private well owners in the Owens Lake area for their cooperation with sampling efforts. Obtaining water quality data through online reporting (local community service district wells, landfill monitoring wells, etc.) was utilized when necessary.

4. Results

4.1 Well Category

Indicator constituent concentration trends can be observed spatially in and around Owens Lake. However, water quality generally varied with the depth of the wells, as the groundwater is drawing of from different aquifer. To separate trends across well depths, wells are categorized as either shallow (0-200 ft below ground surface [bgs]), intermediate (200-800 ft bgs), or deep (800+ ft bgs). All water quality results from the field and laboratory analysis for the 2019 water quality sampling are presented in Table 2.

Shallow wells are considered as wells that are screened in the upper surficial aquifers at Owens Lake bed, on alluvial fans, and on valley floor north or south of Owens Lake. The surficial aquifer on the lake bed is up to approximately 60 feet thick and shallow wells are typically screened above the first thick aquitard. Majority of the shallow wells on the lakebed are 4 and 30 feet deep and were installed by GBUAPCD. Alluvial fan wells are screen within the unconfined aquifer and are up to approximately 300 feet deep. Similarly, wells on the valley floor that are screened within the unconfined aquifer are categorized and shallow wells.

Intermediate wells are generally screened between 200 and 800 feet deep and generally access the second and/or third aquifers, which are the most productive aquifers. These aquifers are separated by thick clay layers. Deep wells are generally screened below 800 feet and access the fourth and/or fifth, less productive aquifers.

Locations of wells categorized as shallow, intermediate, or deep are shown in Figure 4. More details (i.e. depths, diameters, screening, water levels, flow rates, artesian pressure) regarding the sampling locations can be found in Table C.1 of Appendix C.

4.2 Statistical Summary

A statistical analysis of the water quality sampling results is presented in Table 3. Shallow wells tend to have a higher concentration of constituents, while intermediate and deep wells tend to have lower and non-detectable (ND) concentrations. This trend is clearly exhibited in the results presented in Table 3. Of the over 100 sampling locations, the numbers of locations with concentrations above their respective MCLs, SMCLs, or CA-NL were 50 for arsenic, 74 for boron, 33 for fluoride, 11 for uranium, and 72 for TDS.

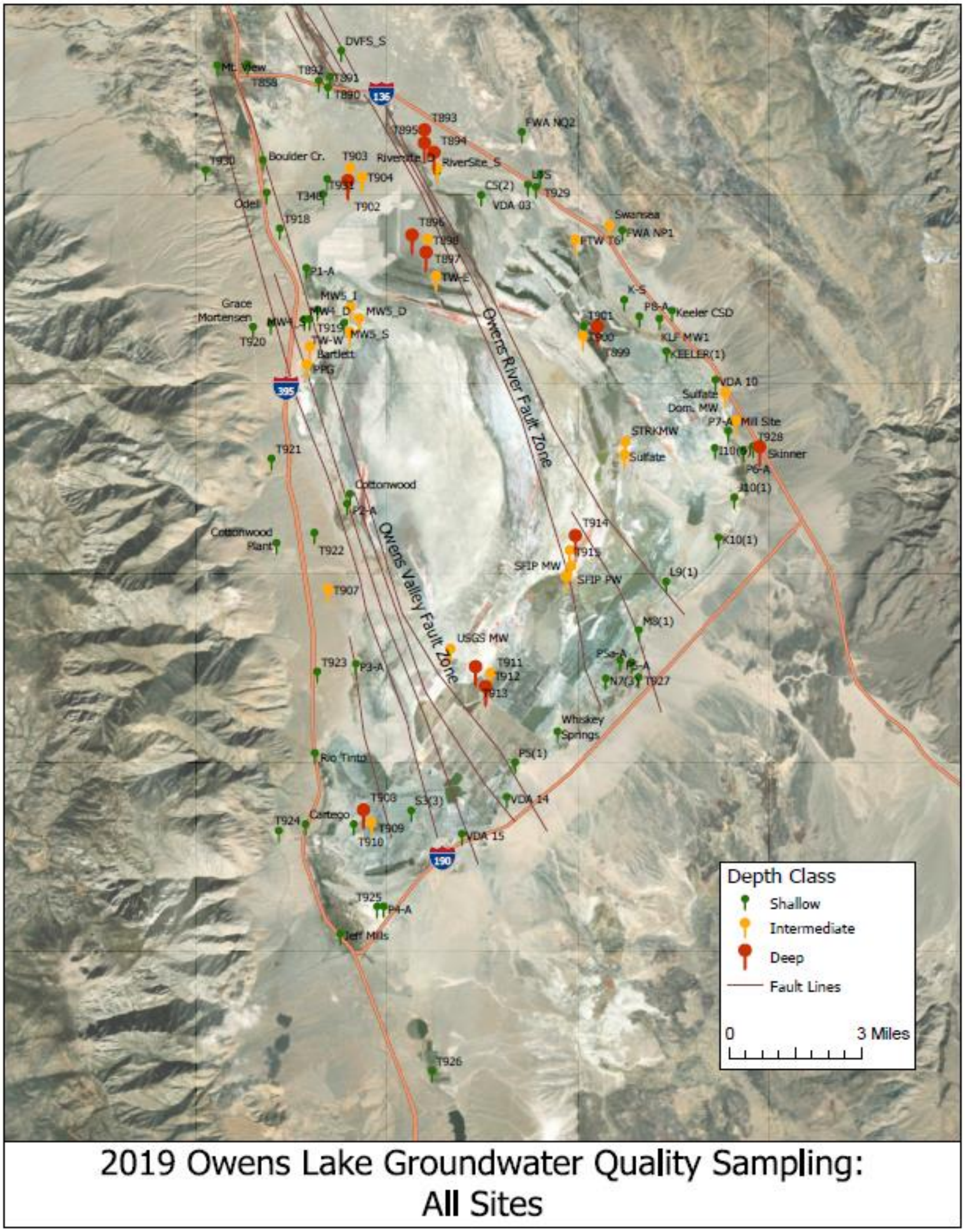

Figure 5: Sampling locations and their depth classifications during 2019 Sampling

Table 2: Results of Owens Lake water quality sampling in 2019

Well	Depth Class	Arsenic (mg/L)	Boron (mg/L)	Fluoride (mg/L)	Uranium (mg/L)	TDS (mg/L)
Mt. View Trailer Park	Shallow	0.0020	ND	0.239	0.001	79
T922	Shallow	ND	0.0524	0.103	0.00075	124
T920	Shallow	0.0072	0.0523	0.293	0.0023	168
MW4_S	Shallow	0.0094	0.0909	0.598	ND	181
MW4_D	Shallow	ND	0.422	1.02	ND	187
Cartego Mutual	Shallow	0.0029		0.52		190
T925	Shallow	0.0077	0.144	0.308	ND	229
Jeff Mills Well	Shallow	ND	0.42	0.193	0.0019	239
T926	Shallow	ND	0.54	0.608	0.0197	264
T924	Shallow	0.0041	0.106	2.18	0.0466	269
T858	Shallow	ND	0.0829	0.225	0.0049	274
P4 A – Deep	Shallow	ND	ND	0.391	ND	341
Grace Mortensen	Shallow	0.0387	ND	0.97	0.0148	403
T921	Shallow	0.0114	1	0.669	0.0139	404
Boulder Cr. RV Park	Shallow	0.004	1	1.92	0.0348	425
T930	Shallow	0.0301	ND	0.554	0.0303	441
T931	Shallow	0.0034	ND	0.695	ND	578
T929	Shallow	ND	2	1.2	ND	674
VDA 03	Shallow	0.0395	2	0.791	0.00058	683
Keeler CSD	Shallow	0.0830	3	1.2	ND	820
VDA 10	Shallow	0.6920	3	0.626	0.0052	898
Keeler LF MW#1	Shallow					910
T919	Shallow	0.2160	5	1.16	0.0017	1,220
T928	Shallow	0.1080	8	4.93	ND	1,300
P2 A	Shallow	0.0193	8	0.398	0.0006	1,400
T348	Shallow	ND	4	3.76	ND	1,460
P1-A	Shallow	0.0831	5	1.15	ND	1,560
P7-A	Shallow	0.14	10	2.85	ND	1,930
P6-A	Shallow	0.6370	16	5.29	0.0039	2,100
P3-A	Shallow	0.17	13	3.17	0.0011	2,160
T923	Shallow	0.0761	24	1.75	0.0039	3,350
VDA 15	Shallow	1	24		0.0137	3,540
L9(1)	Shallow	ND	23	0.681	0.0074	3,900
P5-A	Shallow	0.0060	26	4.13	ND	3,930
K10(1)	Shallow	0.1180	25	1.25	0.0017	3,990
J10(1)	Shallow	0.0796	11	4.46	0.004	4,060
T927	Shallow	0.0924	22	3.16	ND	4,280
P5a-A	Shallow	0.0261	34	3.09	0.0013	4,550
VDA 14	Shallow	0.0082	21	5.31	ND	4,780
Whiskey Springs	Shallow	0.0282	34	4.33	ND	6,040

Well	Depth Class	Arsenic (mg/L)	Boron (mg/L)	Fluoride (mg/L)	Uranium (mg/L)	TDS (mg/L)
M8(1)	Shallow	0.4670	37	1.72	0.0336	6,480
T918	Shallow	0.0757	38	2.85	0	8,990
P5(1)	Shallow	2	111	6.03	0.14	18,600
N7(3)	Shallow	2	152	10.1	0.0548	36,300
KEELER(1)	Shallow	10	274	12.6	0.685	61,200
S3(3)	Shallow	7	203	13.6	0.233	61,200
C5(2)	Shallow	11	264	19.8	0.671	62,800
I10(5)	Shallow	18	326	231	0.0152	86,100
Cottonwood Well	Shallow	0.0040	30	ND	0.006	3,490
Rio Tinto	Shallow	0.0045	ND	1.08	ND	160
FW Aggregates Well	Shallow	0.0431	2	1.28	0.0038	732
FW Aggregates Well	Shallow	0.0352	2	1.19	0.0022	843
T892	Shallow	0.0050	1	0.73	ND	338
T891	Shallow	0.0024	2	0.845	ND	376
T890	Shallow	0.0048	3	0.26	ND	705
Down Valley Fault	Shallow	0.0211	1	1.17	0.0013	339
Riversite Shallow	Shallow	ND	1	0.97	ND	380
Cottonwood Polymer	Shallow	ND	ND	0.15	0.00056	101
T901	Shallow	0.0144	14	2.26	0.0032	2,040
MW5_S	Shallow	0.0476	57	1.65	0.0078	8,410
Keeler-Swansea	Shallow	ND	7	1.36	ND	1,600
P8-A	Shallow	0.0093	7	0.94	ND	1,570
Lizard Tail Spring (C4)	Shallow	0.0138	3	2.03	ND	896
Odell	Shallow	0.011	0.1365	1.67	0.0041	158
Mill Site	Intermdeiate	1	22	6.15	0.0183	1,290
T910	Intermediate	0.0014	1	0.67	ND	181
T909	Intermediate	0.0603	1	0.95	0.0015	248
T904	Intermediate	ND	1	1.37	ND	482
T900	Intermediate	0.0065	1	0.70	ND	660
T898	Intermediate	0.0029	2	1.06	ND	676
T907	Intermediate	0.1240	13	4.8	0.001	1,670
Sulfate Well (SW)	Intermediate	ND	10	1.59	ND	2,090
T913	Intermediate	0.0440	180	4.96	ND	21,000
Riversite Deep	Intermediate	ND	2	2.3	ND	590
Skinner	Intermediate	0.0141	5	3.94	0.003	1,010
Star Trek Monitoring	Intermediate	0.0011	8	1.09	ND	1,910
USGS Monitoring Well	Intermediate	0.0037	91	7.19	ND	13,400
Bartlett-CW	Intermediate	0.0256	ND	0.856	0.0015	229
Swansea Domestic	Intermediate	ND	2	1.01	ND	834
PPG	Intermediate	ND	13	2.46	0.0058	1,870
MW5_I	Intermediate	0.0730	21	ND	0.0146	3,620
MW5_D	Intermediate	ND	54	ND	ND	8,910

Well	Depth Class	Arsenic (mg/L)	Boron (mg/L)	Fluoride (mg/L)	Uranium (mg/L)	TDS (mg/L)
Sulfate Domestic MW	Intermediate	ND	36	10.8	0.0954	3,770
Fault Test Well T6	Intermediate	0.0140	10	1.43	0.0028	1,560
T911	Deep	0.0490	0	0.61	ND	6,260
T894	Deep	ND	1	0.56	ND	266
T899	Deep	0.0060	2	0.78	ND	484
T895	Deep	ND	3	0.38	ND	569
T893	Deep	ND	2	0.43	ND	583
T896	Deep	0.0050	3	0.37	ND	592
T902	Deep	ND	3	0.21	ND	637
T903	Deep	ND	3	1.24	ND	829
T908	Deep	0.0500	7	4.32	0.124	882
T897	Deep	0.0024	3	2.53	ND	908
T914	Deep	0.0010	14	1.13	ND	2,600
T912	Deep	0.0010	16	0.50	ND	4,010
T915	Deep	0.0010	25	1.71	ND	4,810
South FIP MW	Deep	0.0030	32	1.75	ND	5,580
South FIP PW	Deep	0.0050	33	2.05	ND	5,780
TW-E	Deep	0.0230	8		ND	1,610
TW-W	Deep	0.4500	145		0.0222	21,600

Table 3: Statistics of 2019 water quality sampling results in mg/L

Constituent		Min	Max	Average
Arsenic (mg/L)	Shallow	ND	17.500	0.848
	Intermediate	ND	0.450	0.068
	Deep	ND	0.050	0.010
Boron (mg/L)	Shallow	ND	326.0	32.9
	Intermediate	0.5	145.0	22.1
	Deep	ND	33.0	7.3
Fluoride (mg/L)	Shallow	ND	231.0	6.0
	Intermediate	0.9	10.8	2.6
	Deep	0.2	4.3	1.2
Uranium (mg/L)	Shallow	ND	0.685	0.033
	Intermediate	ND	0.095	0.007
	Deep	ND	0.124	0.010
TDS (mg/L)	Shallow	79	86,100	6,992
	Intermediate	229	21,600	3,544
	Deep	266	6,260	1,964

4.3 Shallow Wells

Shallow wells located on the lakebed have higher indicator constituent concentrations than those on the alluvial fans. Generally, the closer to the lakebed the higher the concentrations of indicator constituents were observed. When TDS measurement data is displayed spatially over the Owens Lake sampling area, there is an apparent trend of better water quality towards the northwest and poorer towards the southeast (Figure 5). Similar trends exist for arsenic, boron, and uranium (Appendix B). Outliers of this trends include T913, P5(1), N7(3), Keeler(1), S3(3), C5(2), and I10(5). These surficial wells have higher indicator constituent concentrations than other shallow wells along the eastern shoreline. Resampling these wells was suggested to ensure accuracy and consistency and to obtain a sample of Odell well not taken during the first sampling period. S3(3), Keeler(1), and T913 were resampled and all groundwater concentrations of indicator constituents remained within the same ranges.

4.4 Intermediate Wells

Roughly a quarter of all wells sampled are intermediate wells. These are located in the area between Owens Valley and the Owens River faults (Figure 6). Samples from wells outside of this area, specifically on the western side, have better water quality than wells sampled within it. This trend is likely attributed to barrier effects of faulting, which affects the flow of groundwater.

4.5 Deep Wells

Deep wells account for less than a quarter of the wells sampled at Owens Lake. The deeper wells located within the bounded fault zones tend to have better water quality than the shallower (Figure 7). Water in deep wells can be considered “old” water that is minimally affected by recharge from surrounding alluvial fans.

4.6 Cluster Monitoring Wells

The Owens Lake groundwater system consists of multiple aquifers (Figure 1) and aquifers of generally different water quality. LADWP cluster wells screened in three distinct aquifers, when sampled, have varying groundwater indicator constituent concentrations (e.g. T899, T900, and T901, which are constructed at depths of 1,003 ft, 720 ft, and 190 ft bgs respectively). Water quality results exhibit that concentrations of indicator constituents in groundwater generally decrease with depth.

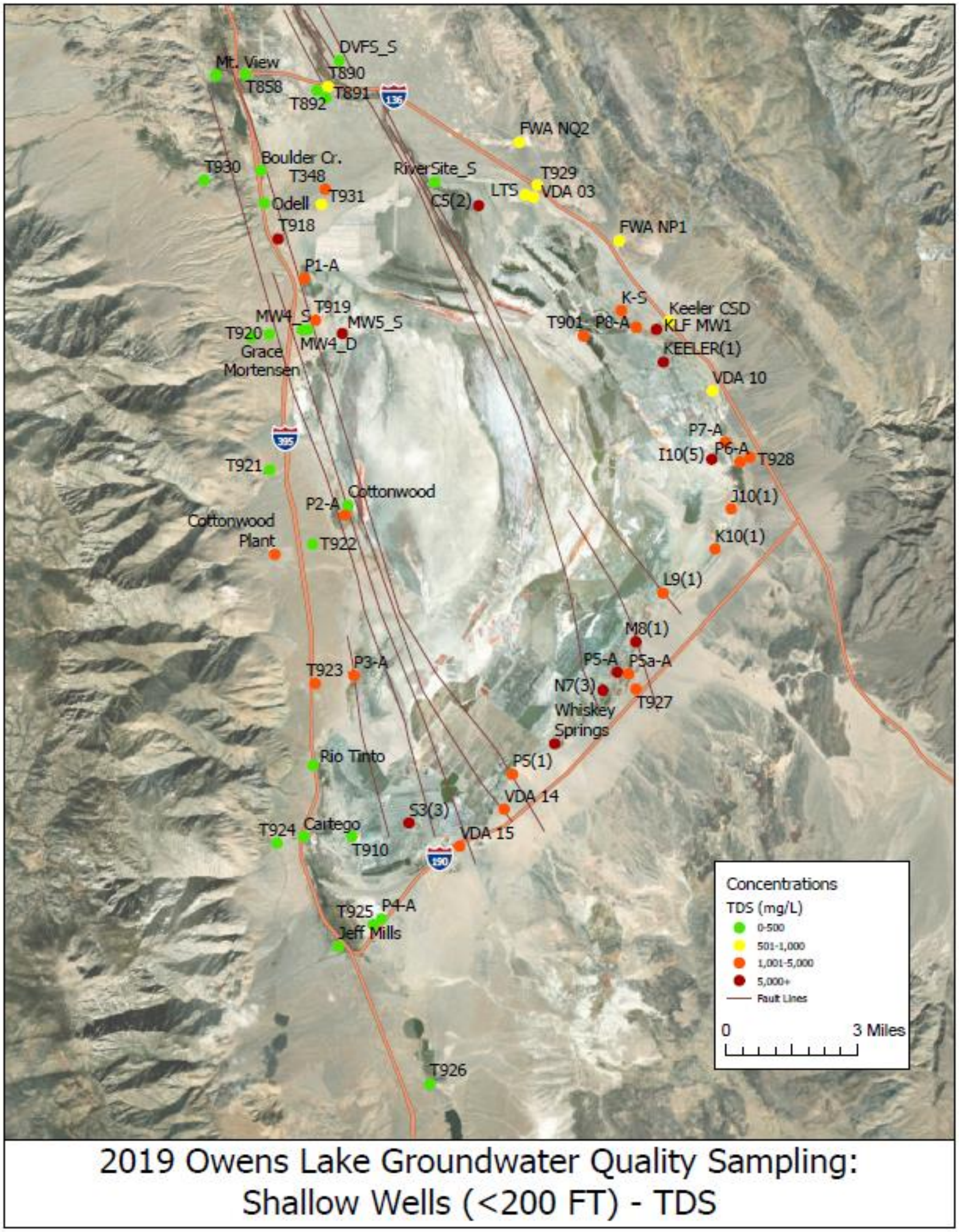

Figure 6: Map showing the concentrations of TDS in shallow wells

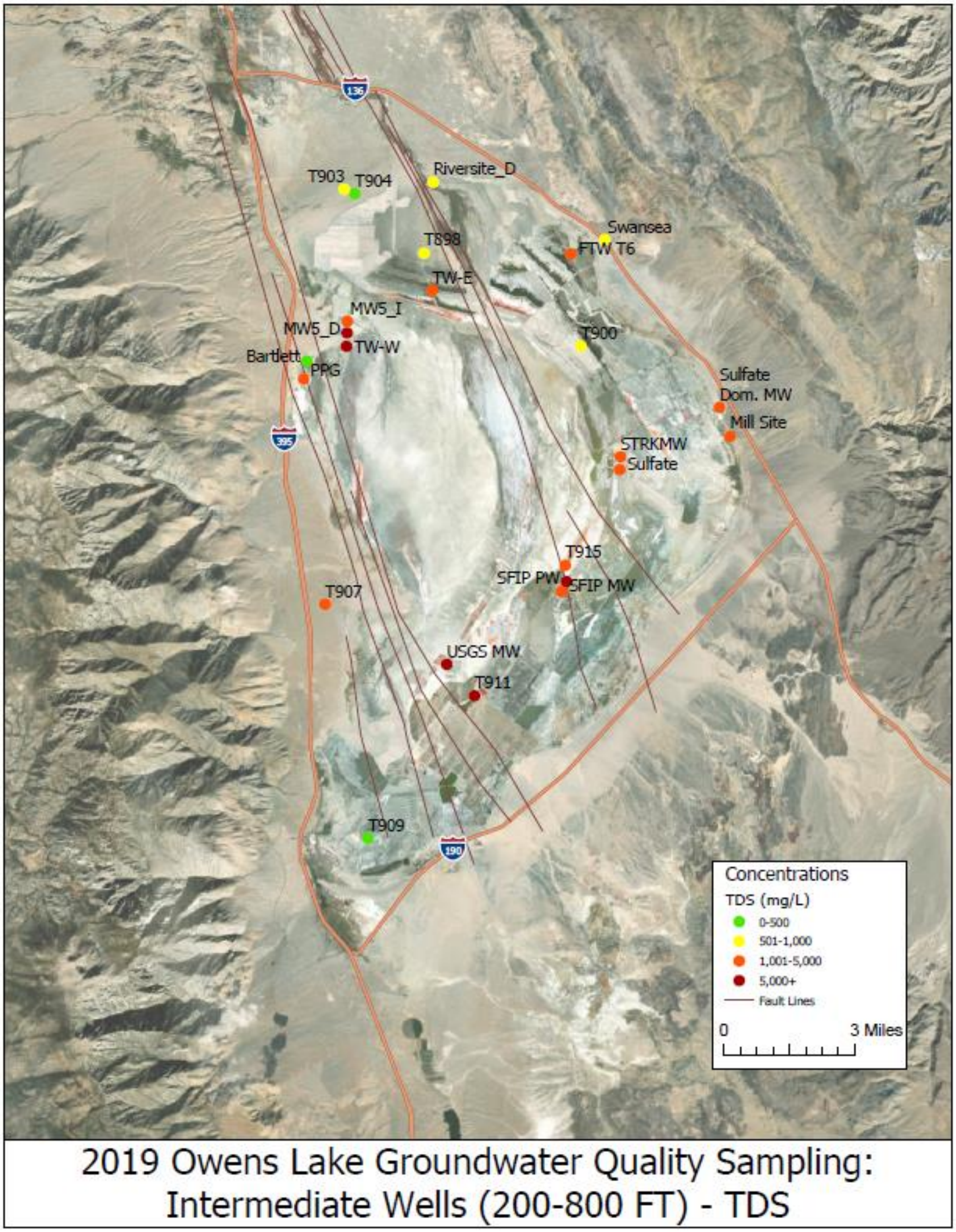

Figure 7: Map showing the concentrations of TDS in intermediate wells

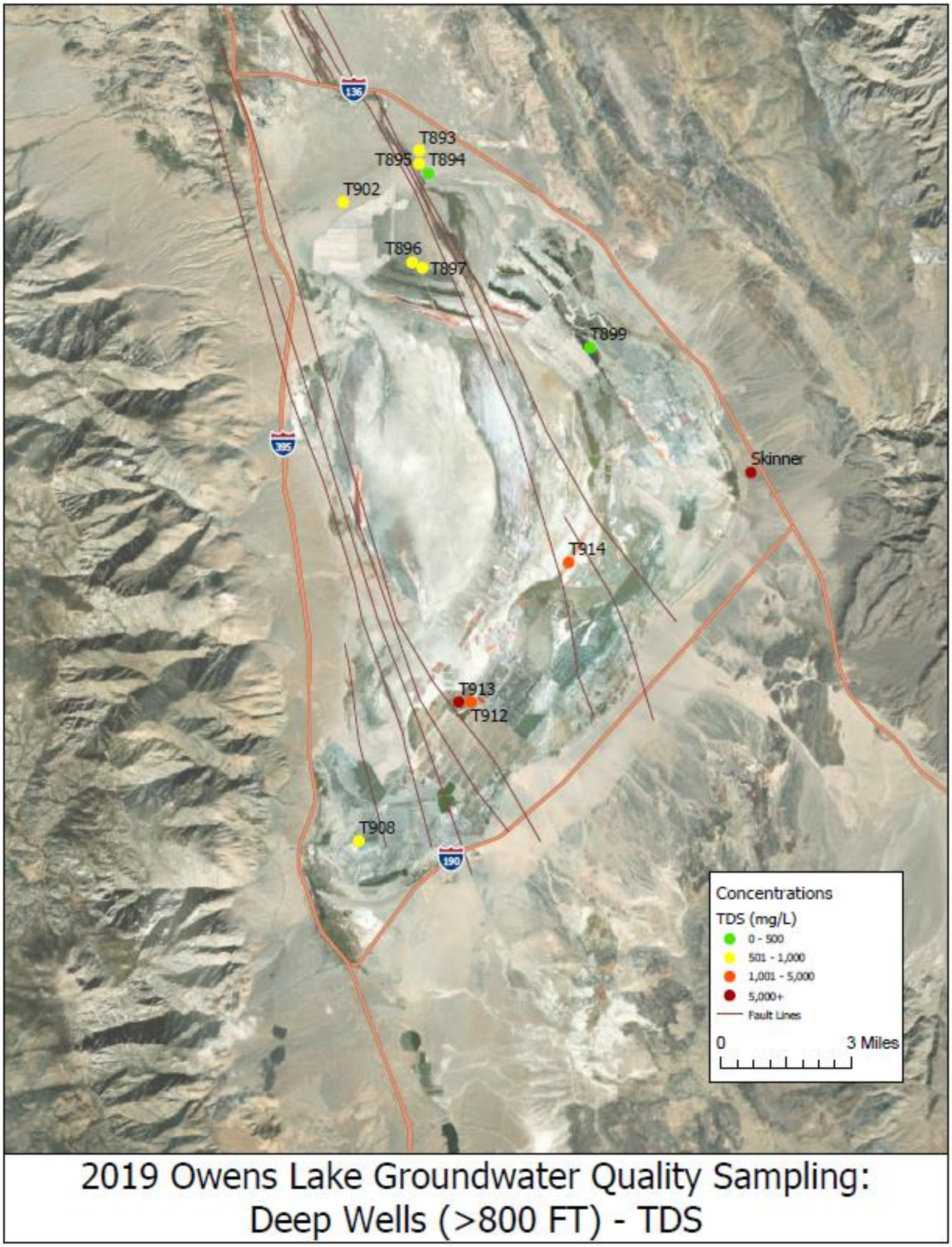

Figure 8: Map showing the concentrations of TDS in deep wells

5. Conclusions

Results of the 2019 sampling show water quality variations based on location and depth with the exception of a few outliers. In the shallow wells, water quality is relatively lower along the eastern and southern shores of Owens Lake and higher along the northern and western shores. Wells located off the lakebed and on alluvial fans have better water quality than those on the lakebed due to mountain front recharge. Also, results of this study indicate that water quality generally improves the deeper the well is screened.

As a component of OLGDP, this report establishes a pre-pumping baseline of the quality of groundwater at Owens Lake. When the proposed groundwater pumping for dust mitigation at Owens Lake occurs, data presented in this report will help quantify the effects of groundwater pumping on water quality by comparing pre-pumping and during pumping.

6. References

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7. Appendices

Any supplemental material to help aid the visualization of results from groundwater quality sampling can be found in the appendices. The supplemental material includes figures, maps, and tables.

Appendix A - Charts

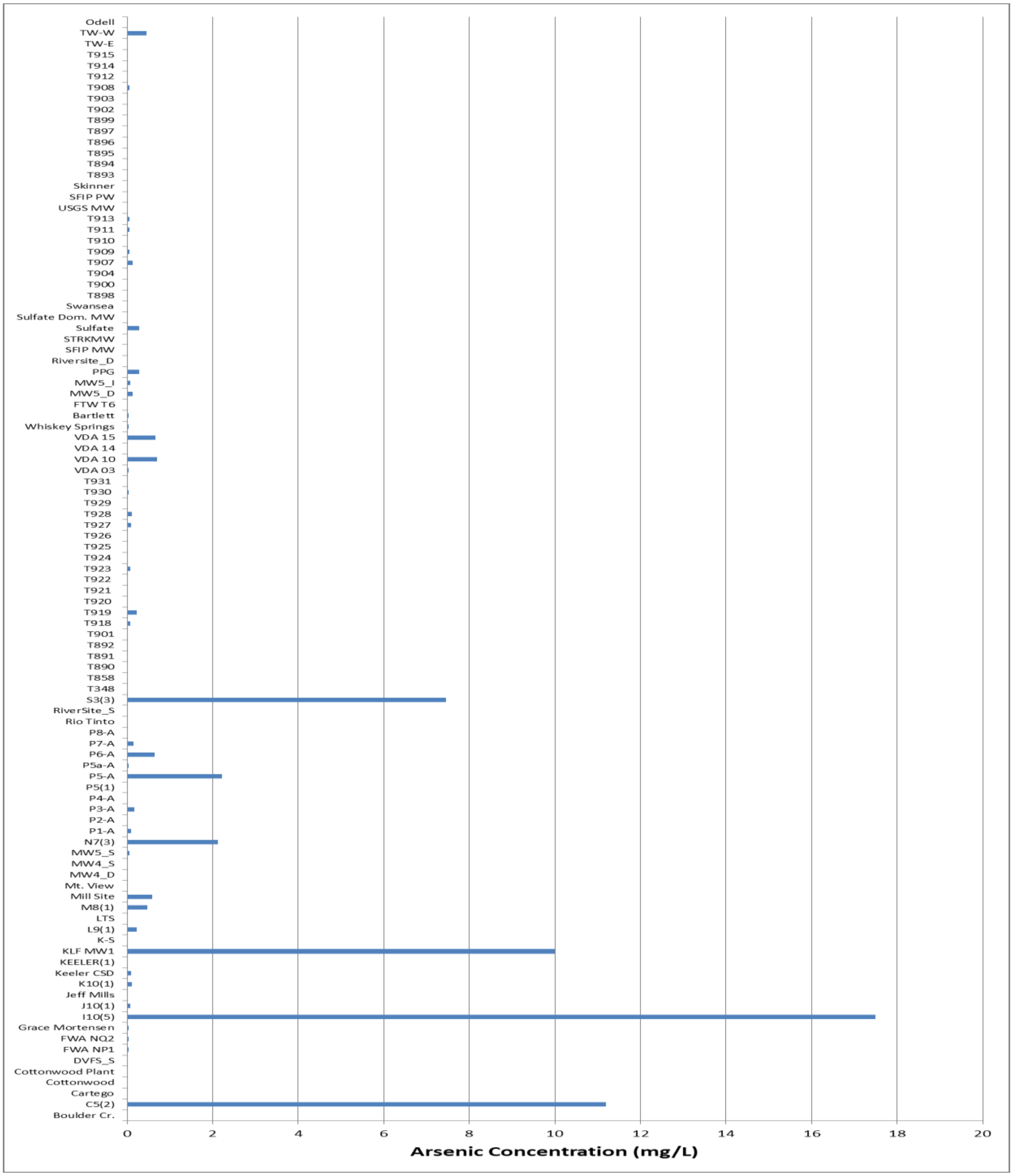


Figure A1: The concentration of arsenic found in all wells throughout Owens Lake

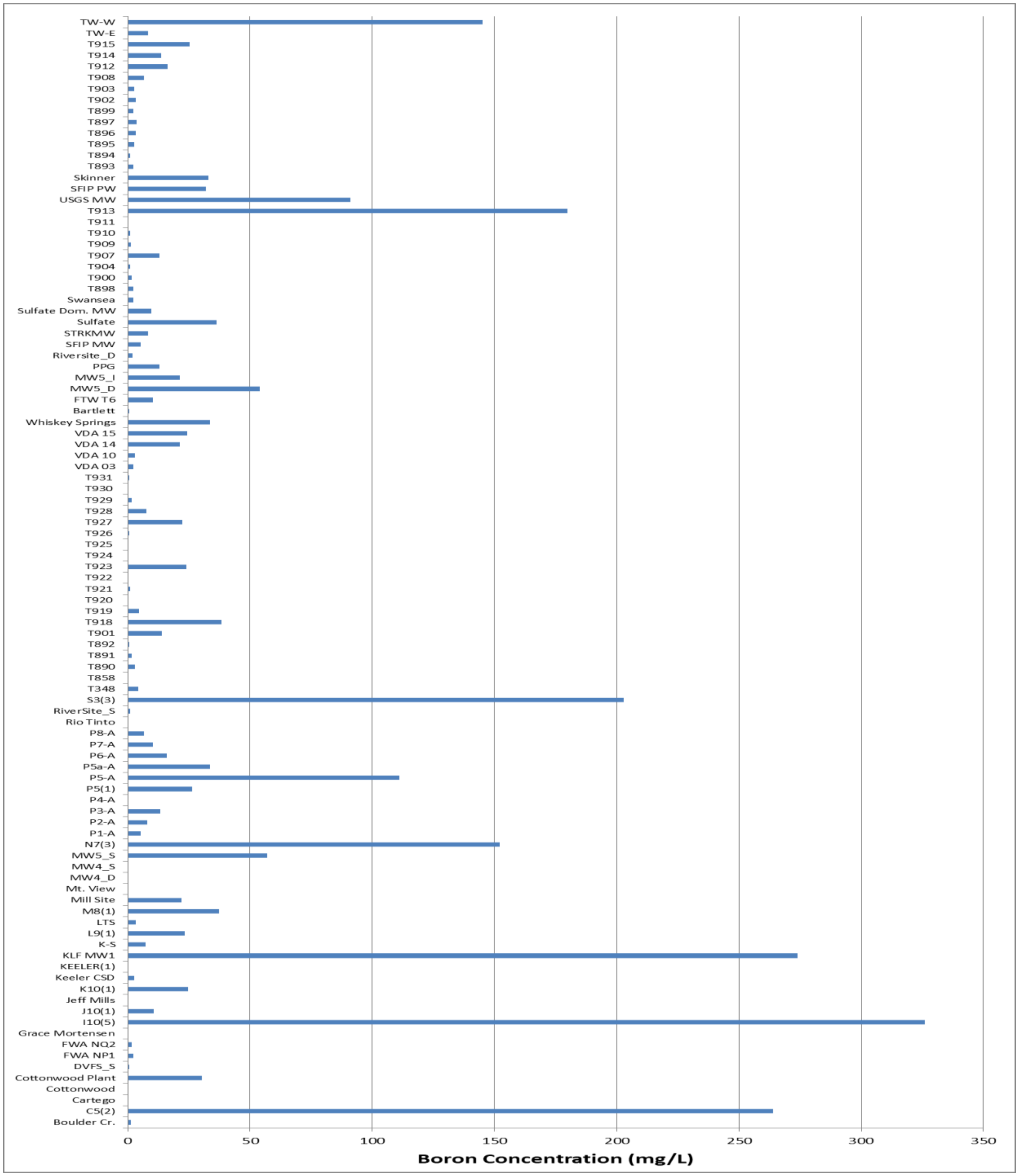


Figure A2: The concentration of boron found in all wells throughout Owens Lake

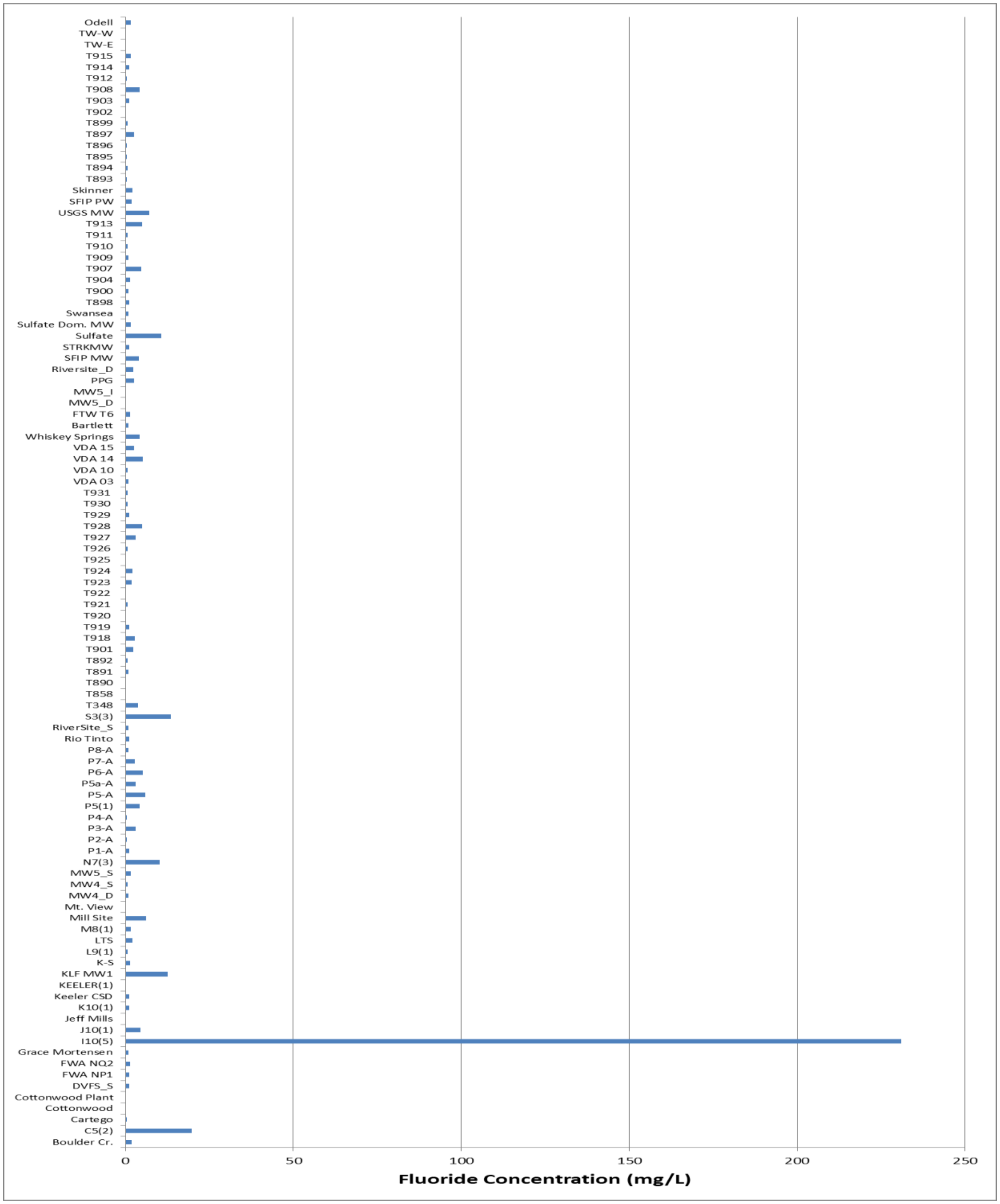


Figure A3: The concentration of fluoride found in all wells throughout Owens Lake

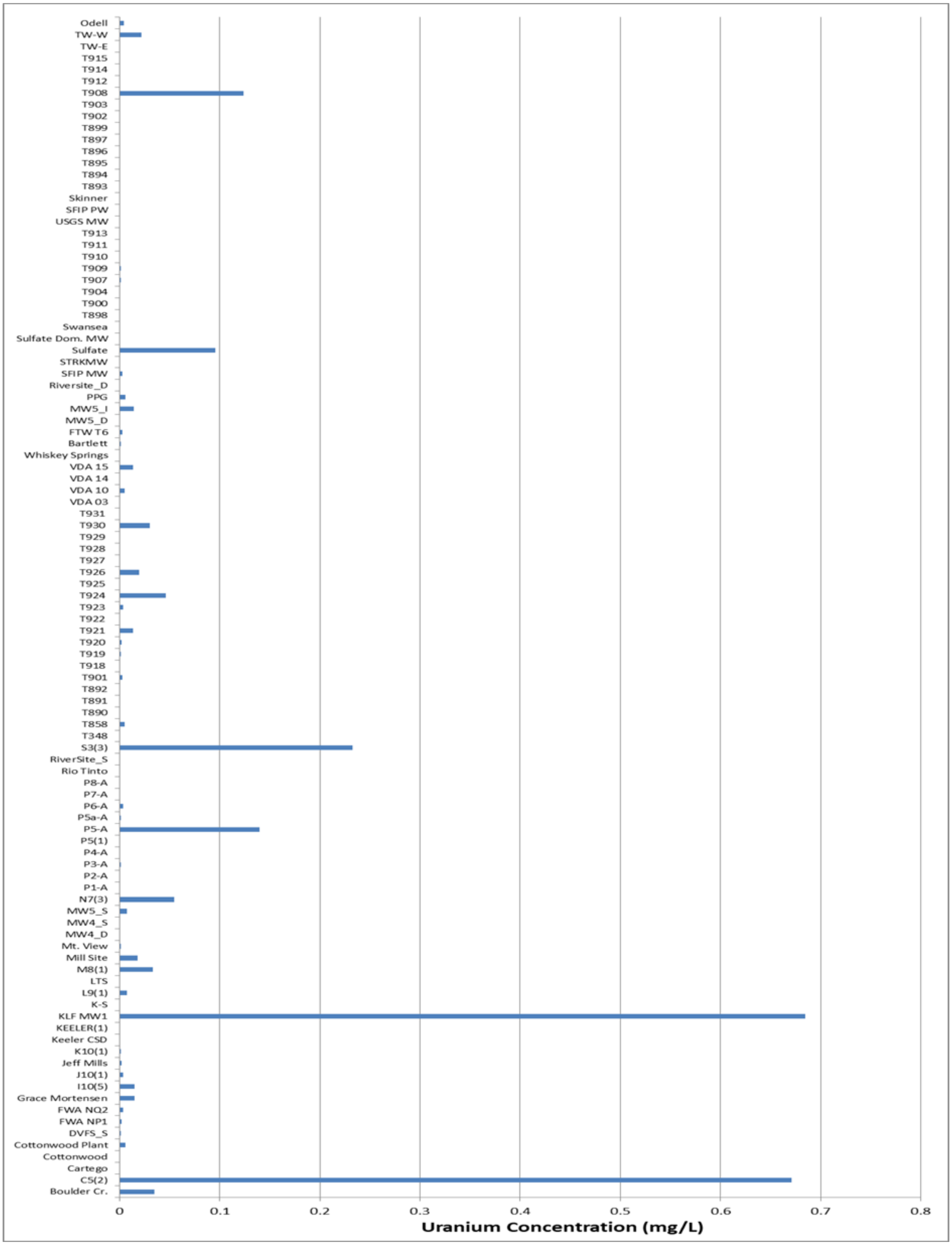


Figure A4: The concentration of uranium found in all wells throughout Owens Lake

Appendix B - Maps

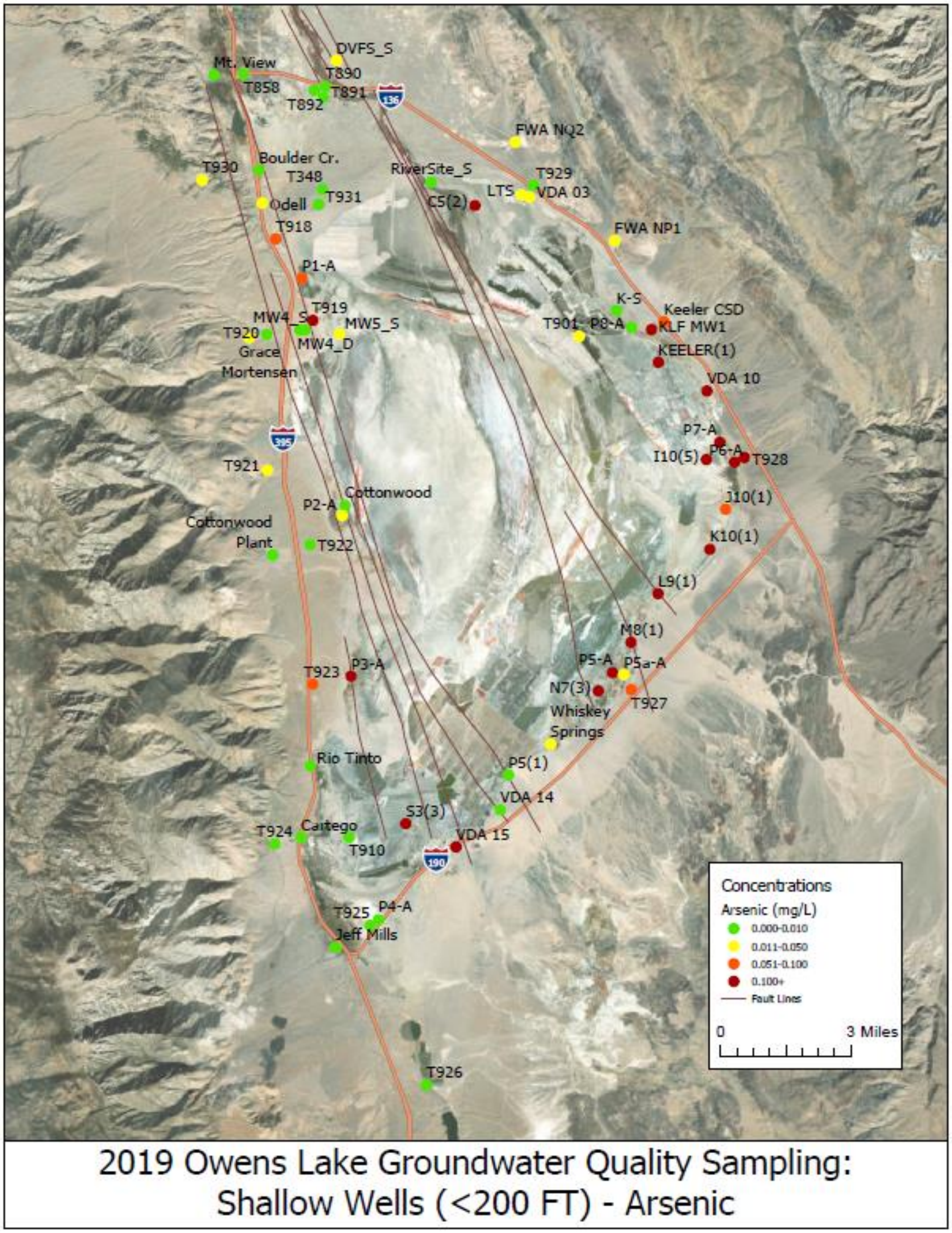


Figure B1: Map showing the concentrations of arsenic in shallow wells

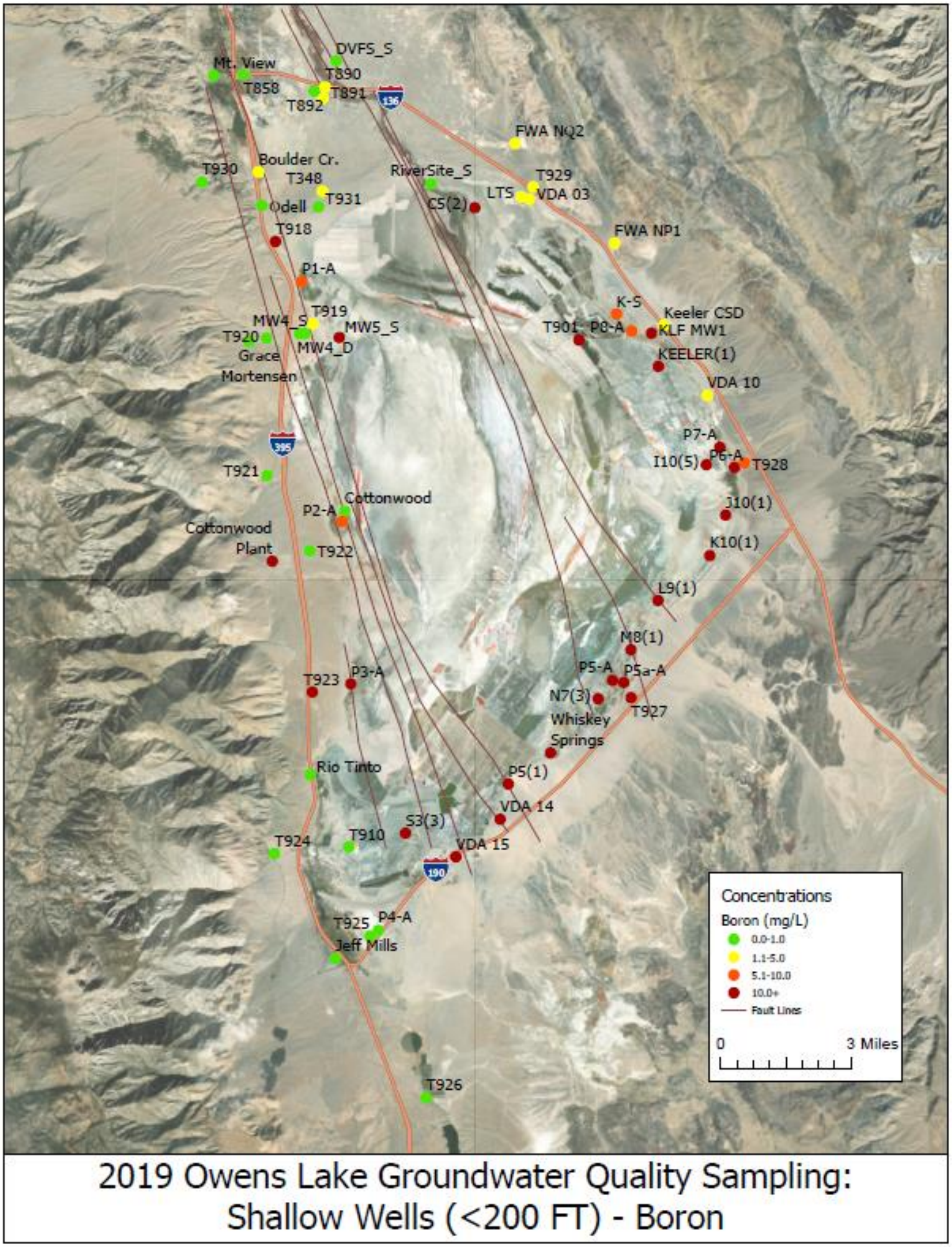


Figure B2: Map showing the concentrations of boron in shallow wells

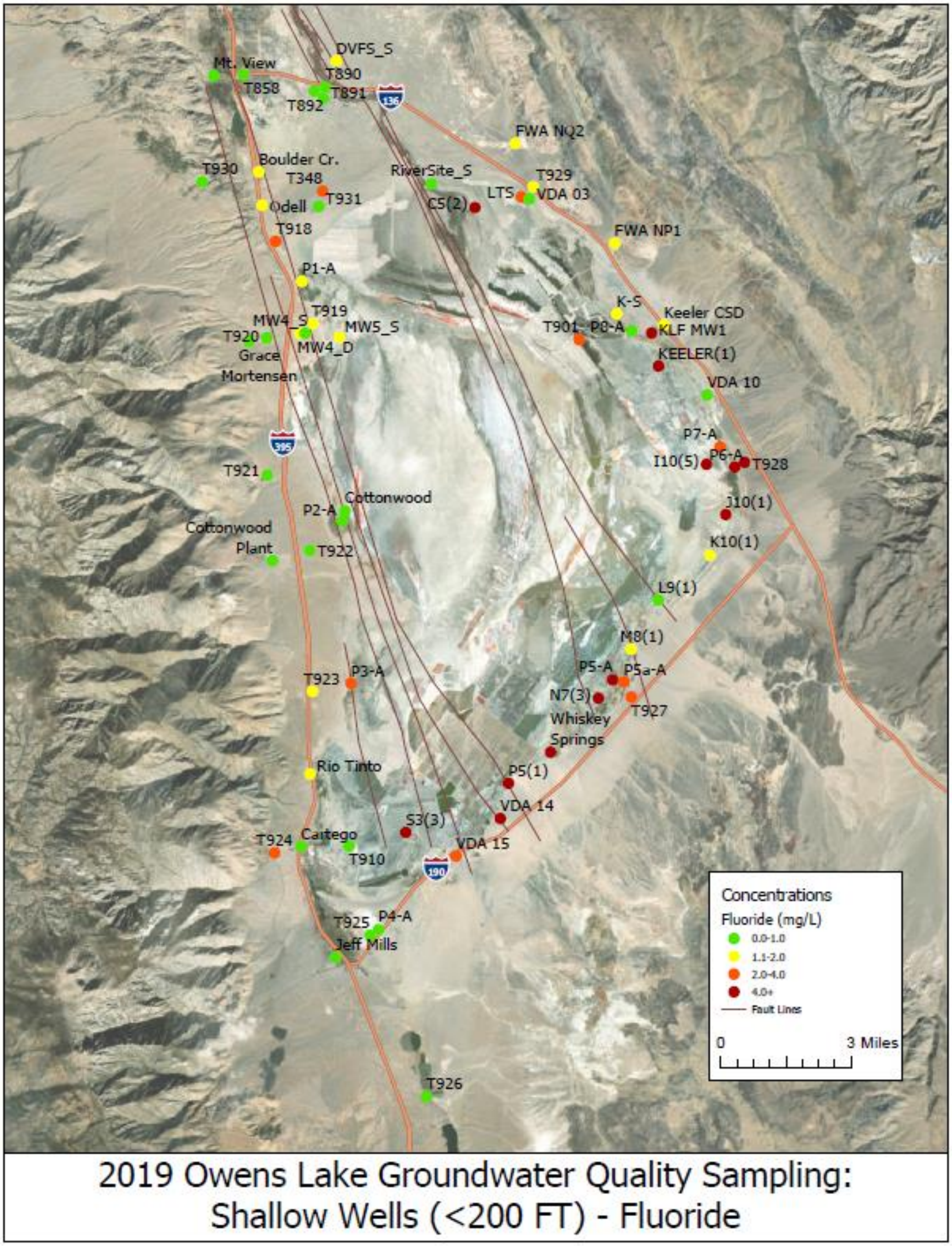


Figure B3: Map showing the concentrations of fluoride in shallow wells

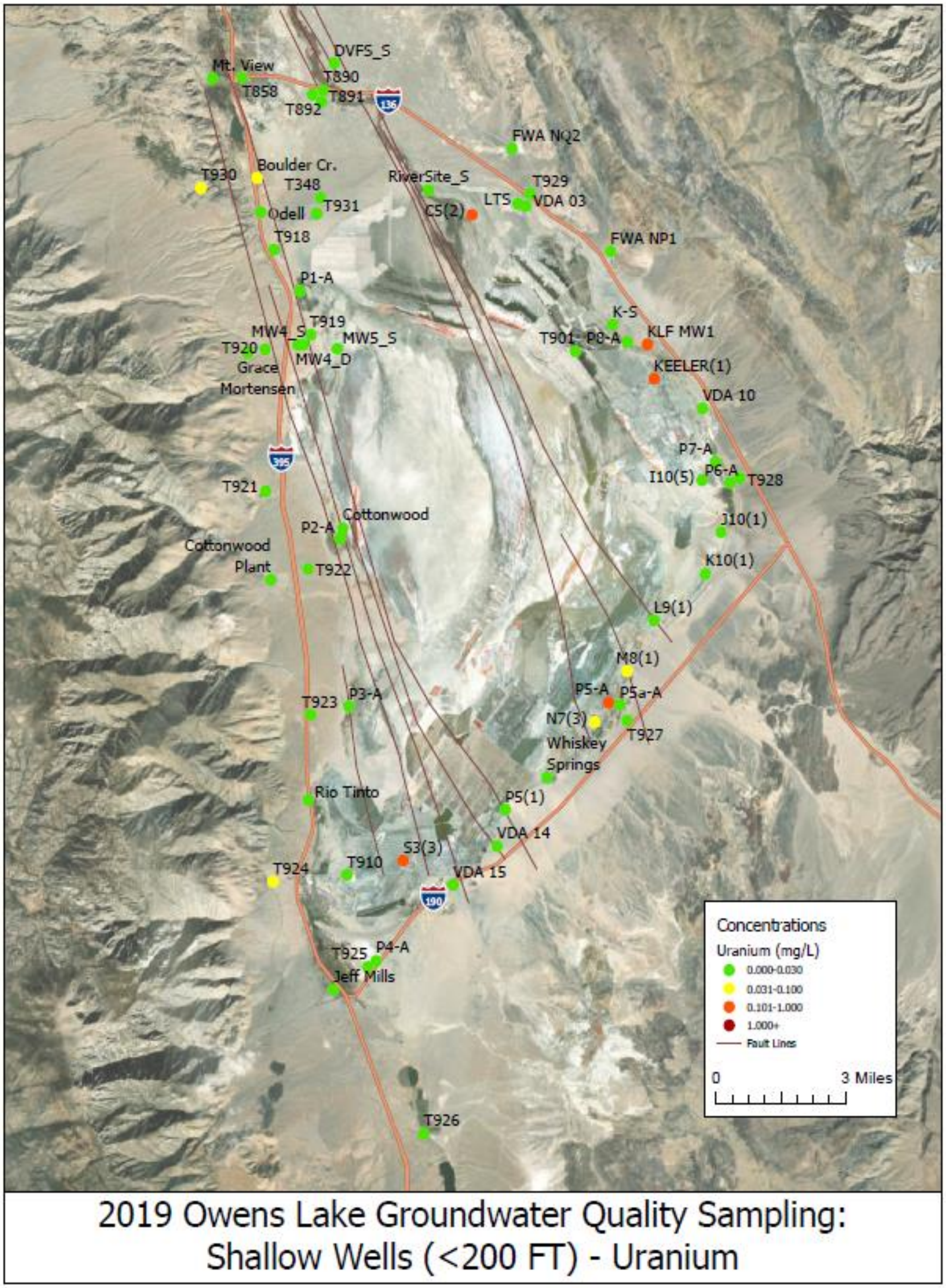


Figure B4: Map showing the concentrations of uranium in shallow wells

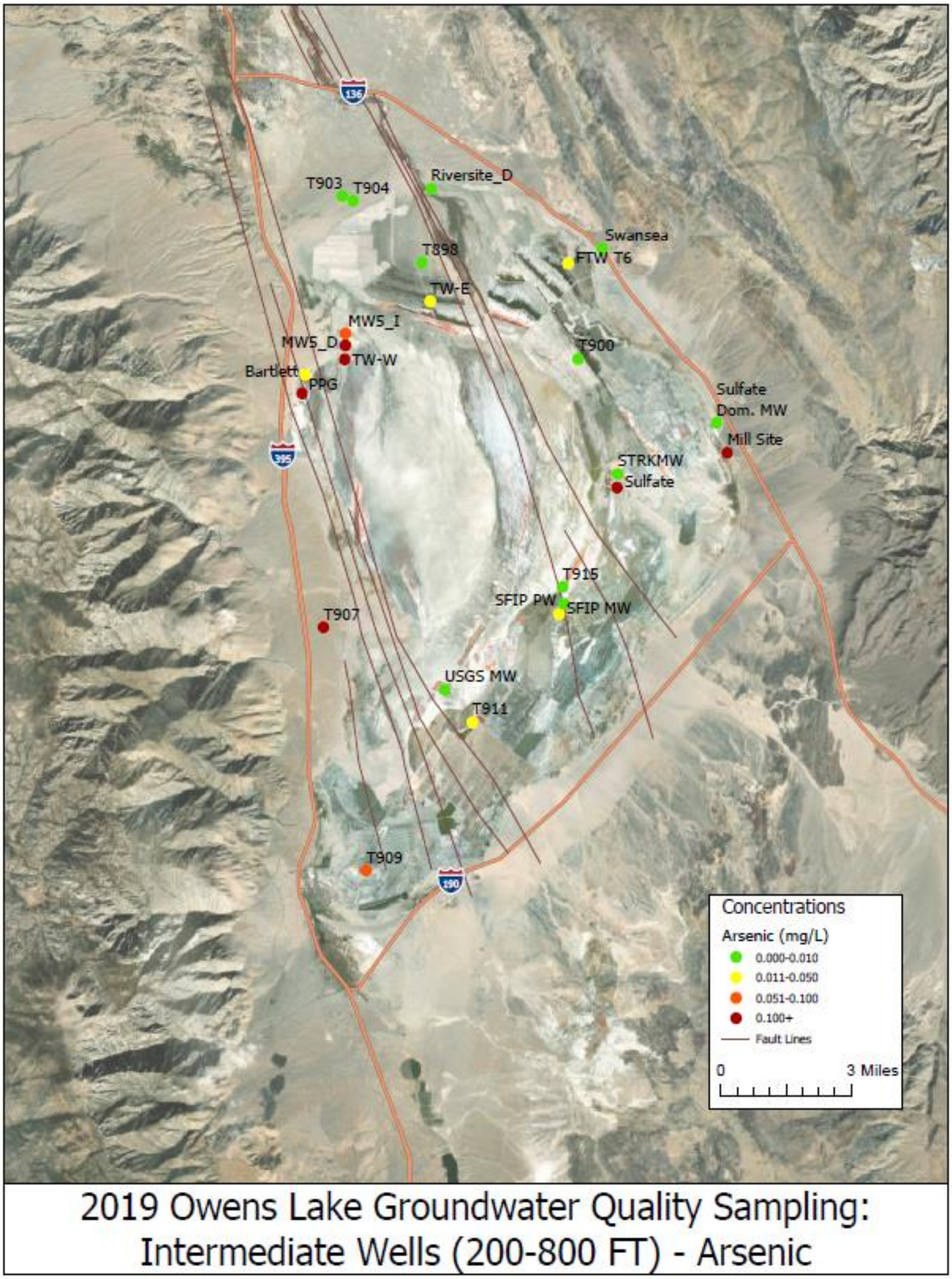
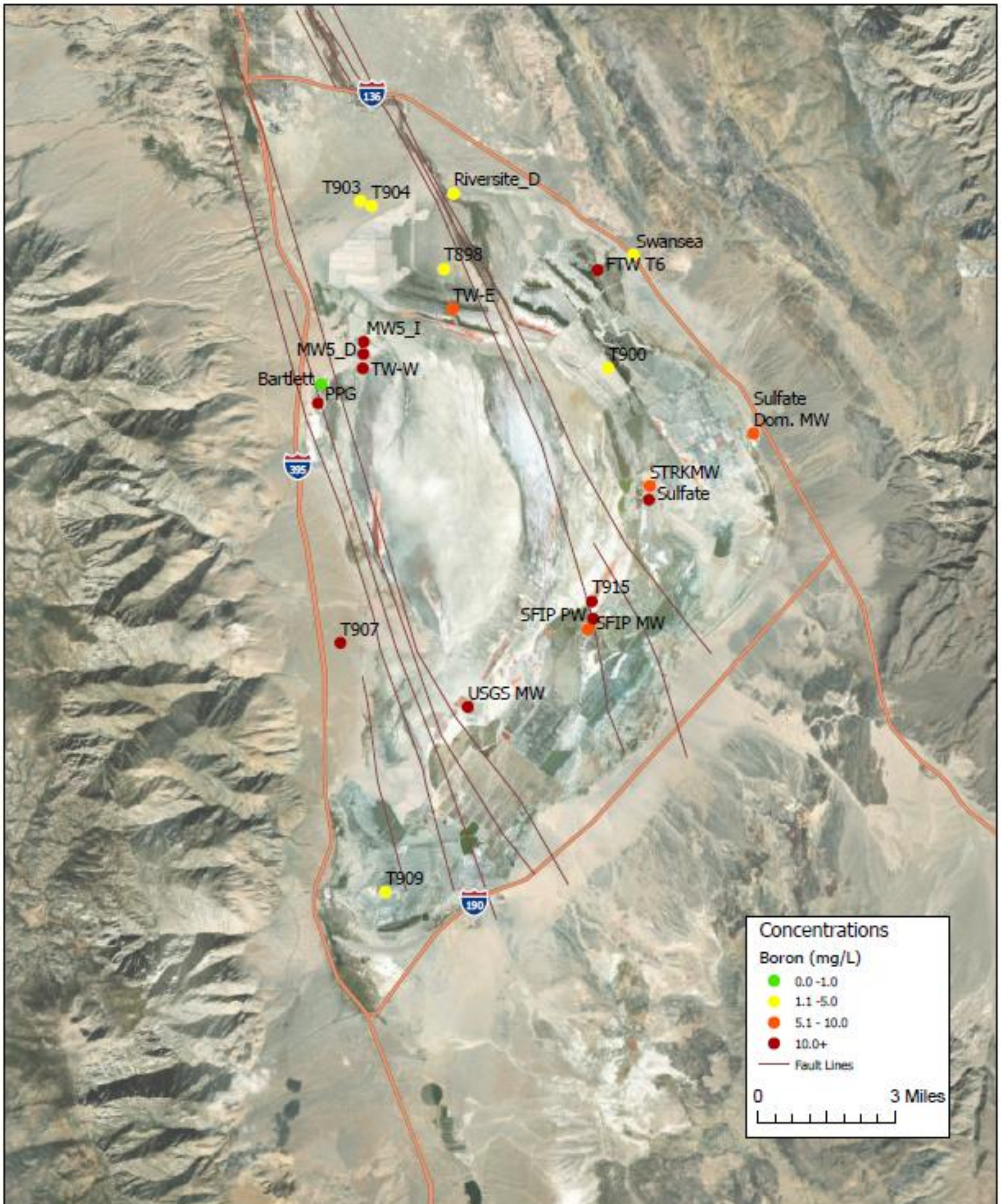


Figure B5: Map showing the concentrations of arsenic in intermediate wells



2019 Owens Lake Groundwater Quality Sampling: Intermediate Wells (300-800 FT) - Boron

Figure B6: Map showing the concentrations of boron in intermediate wells

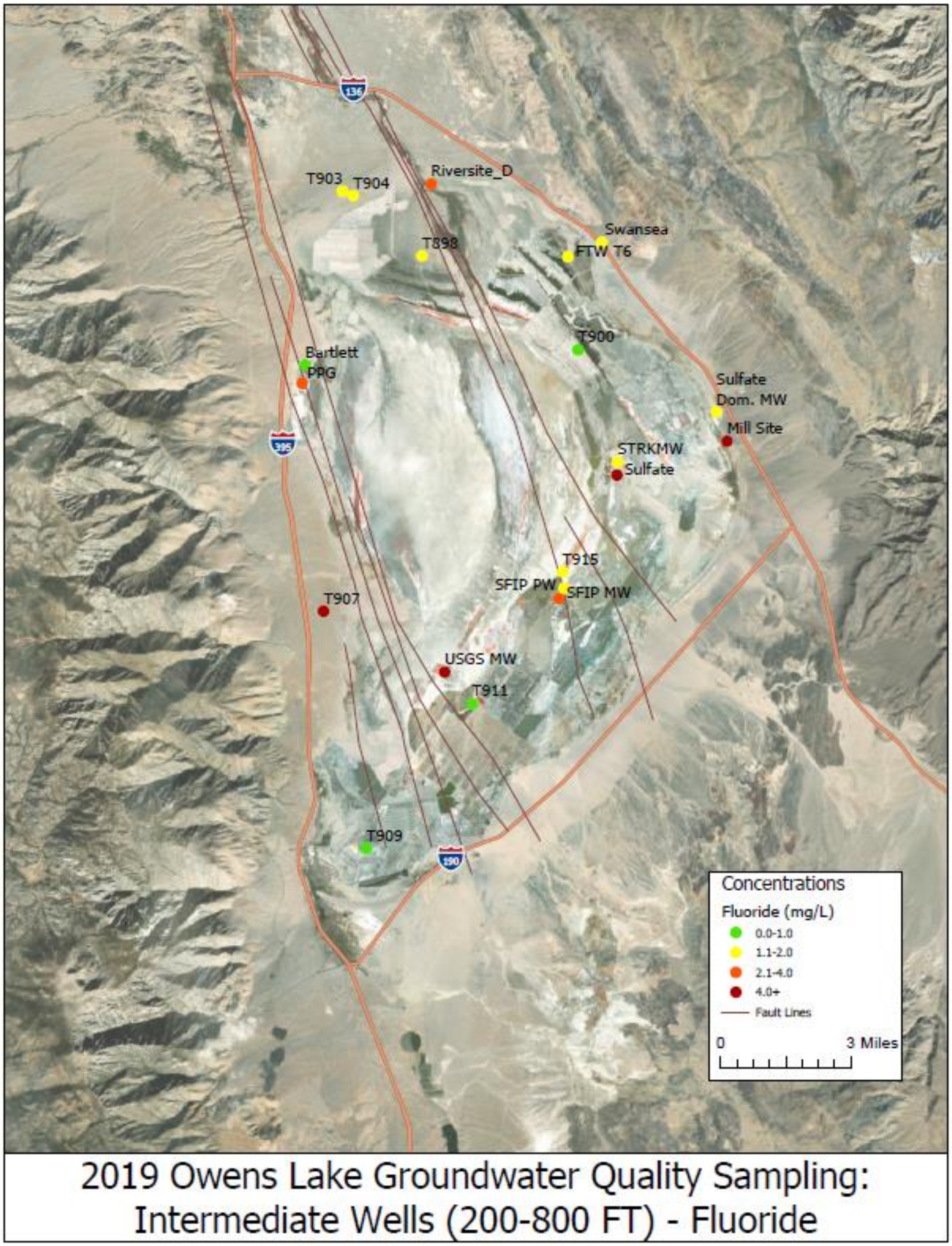


Figure B7: Map showing the concentrations of fluoride in intermediate wells

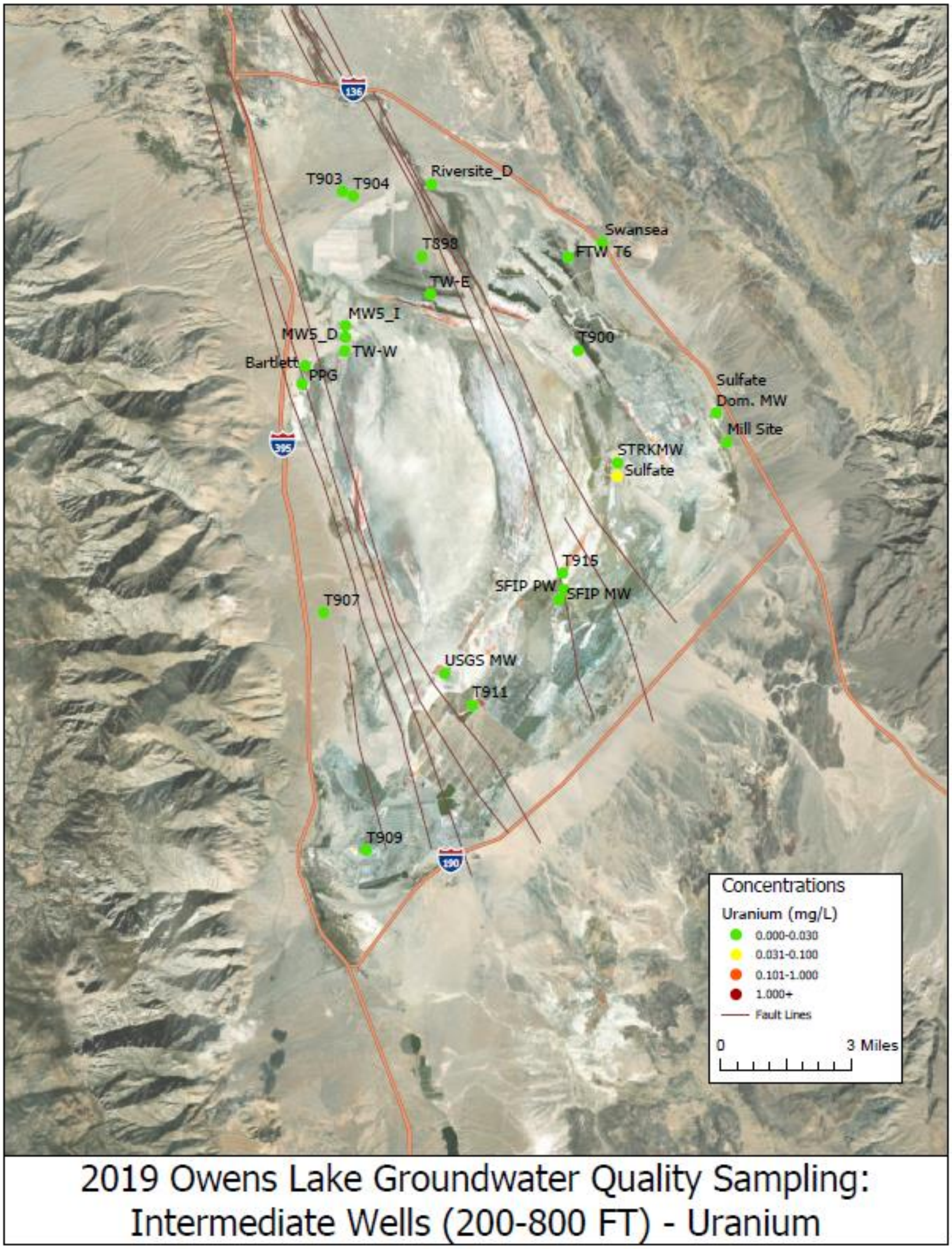


Figure B8: Map showing the concentrations of uranium in intermediate wells

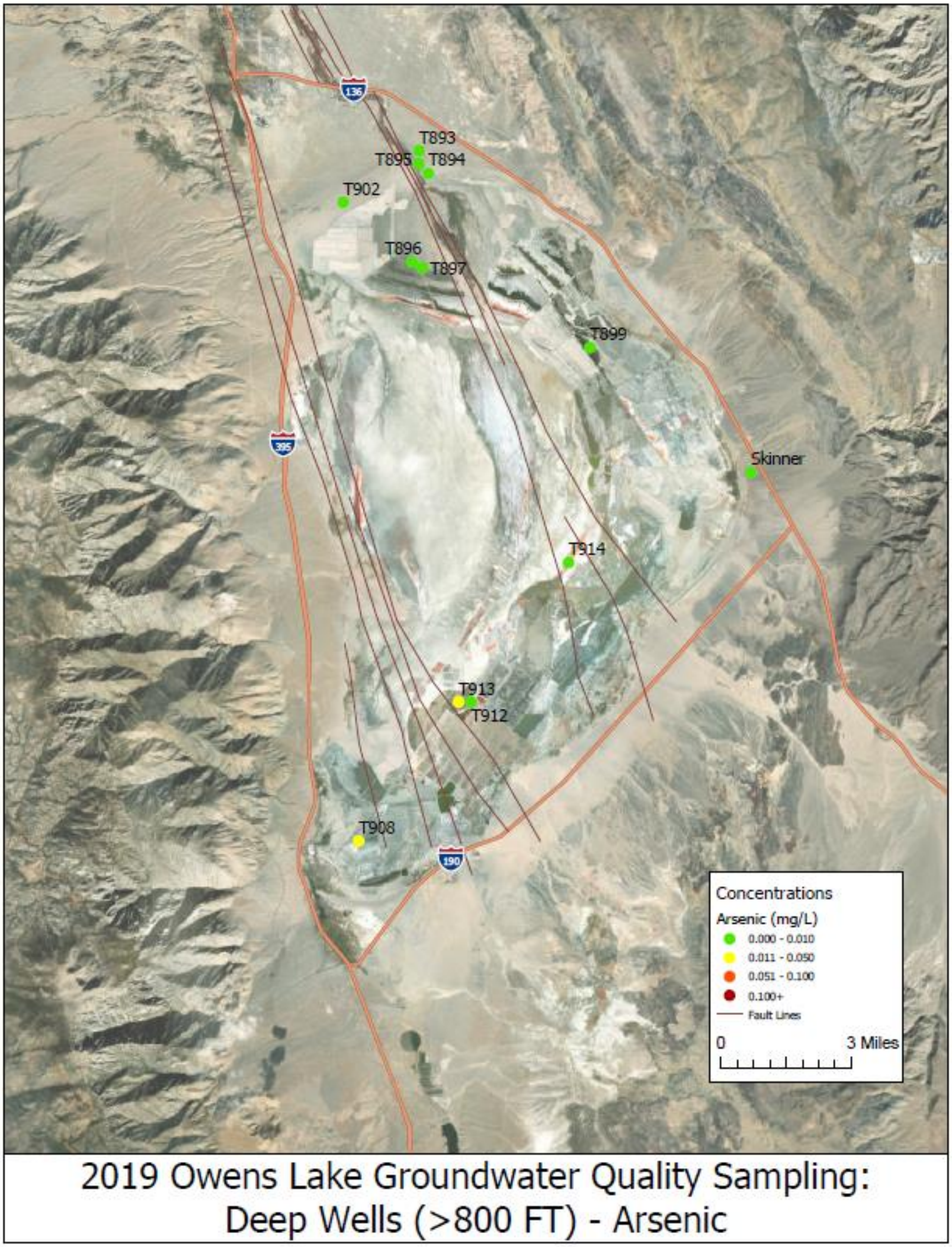


Figure B9: Map showing the concentrations of arsenic in deep wells

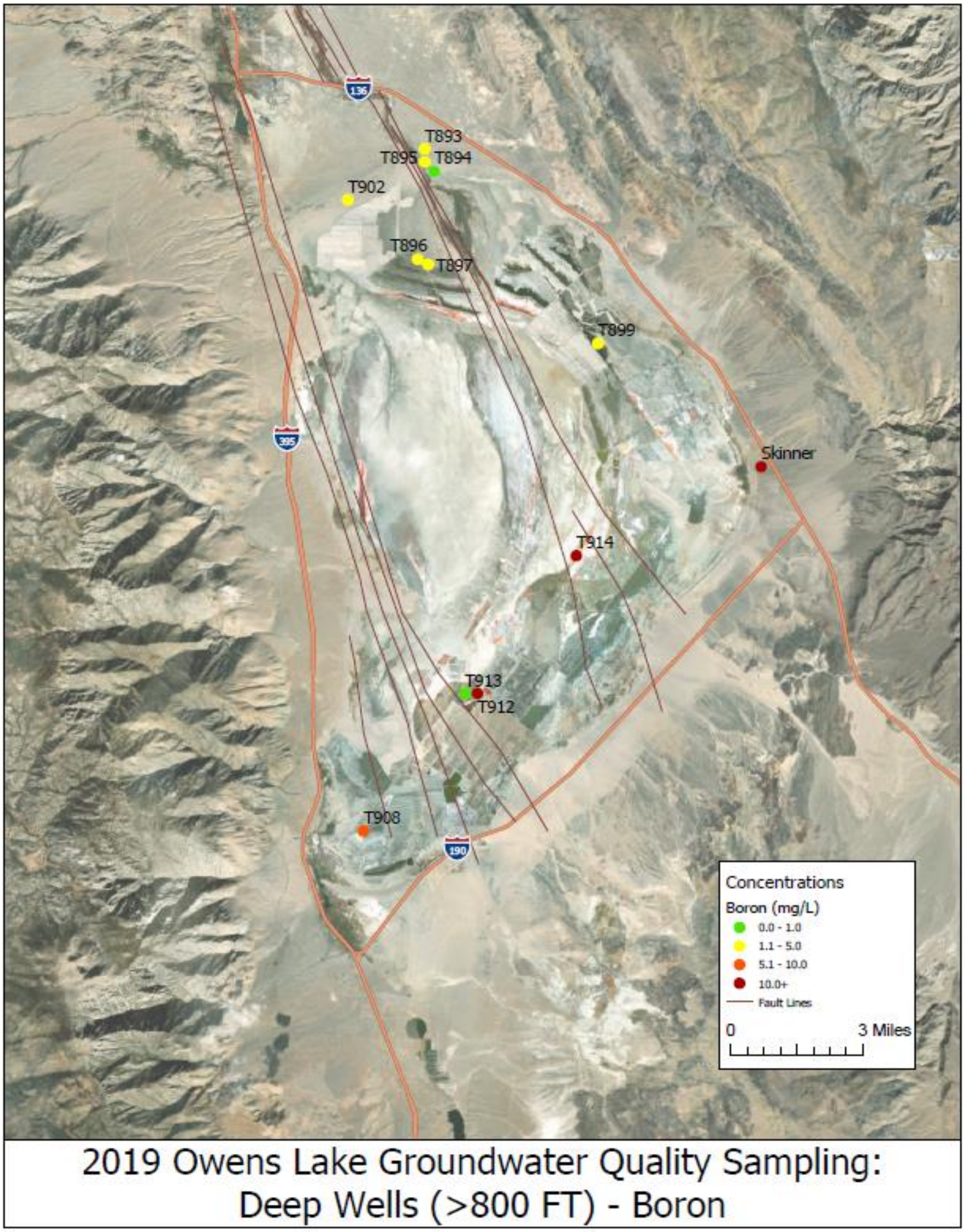


Figure B10: Map showing the concentrations of boron in deep wells

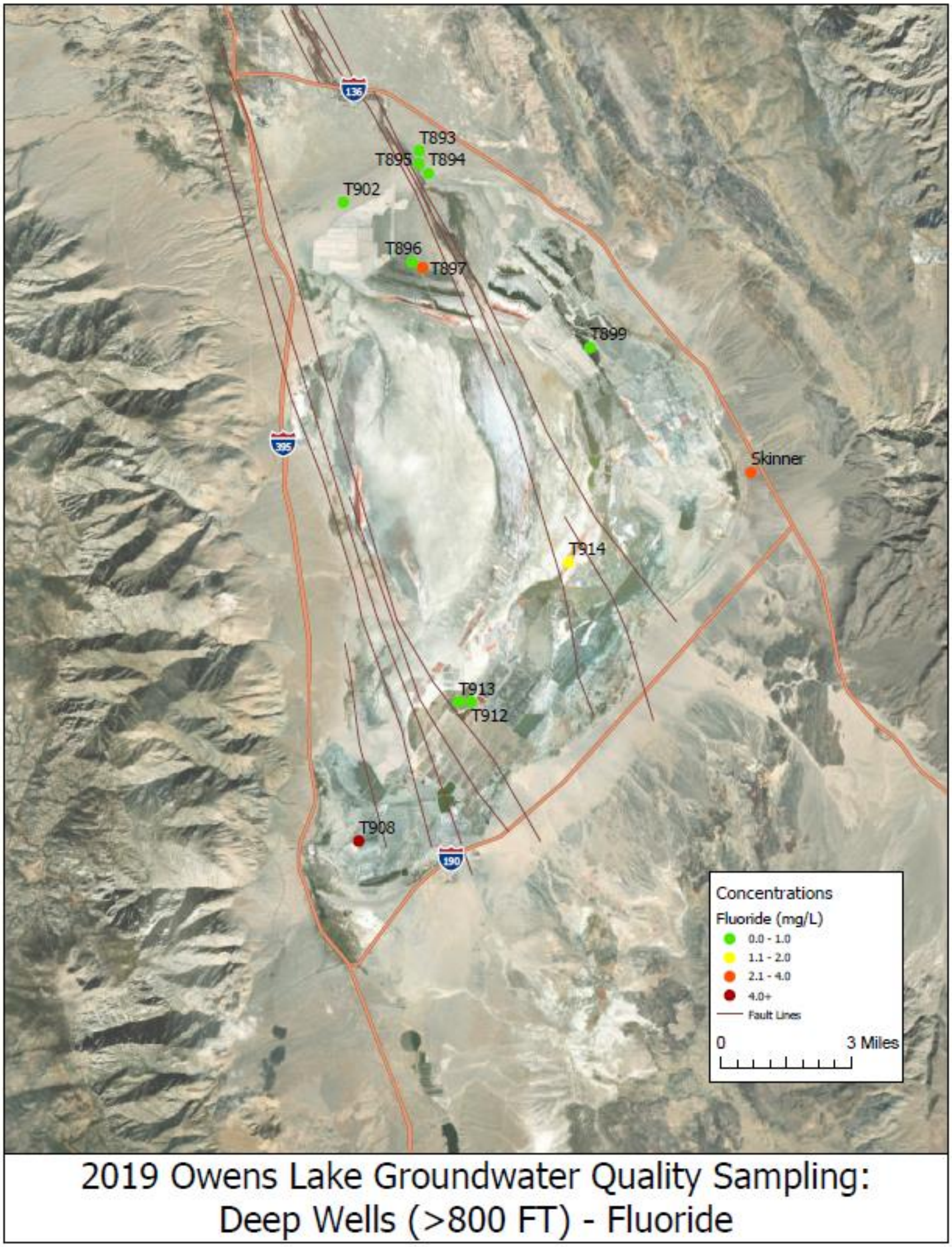


Figure B11: Map showing the concentrations of fluoride in deep wells

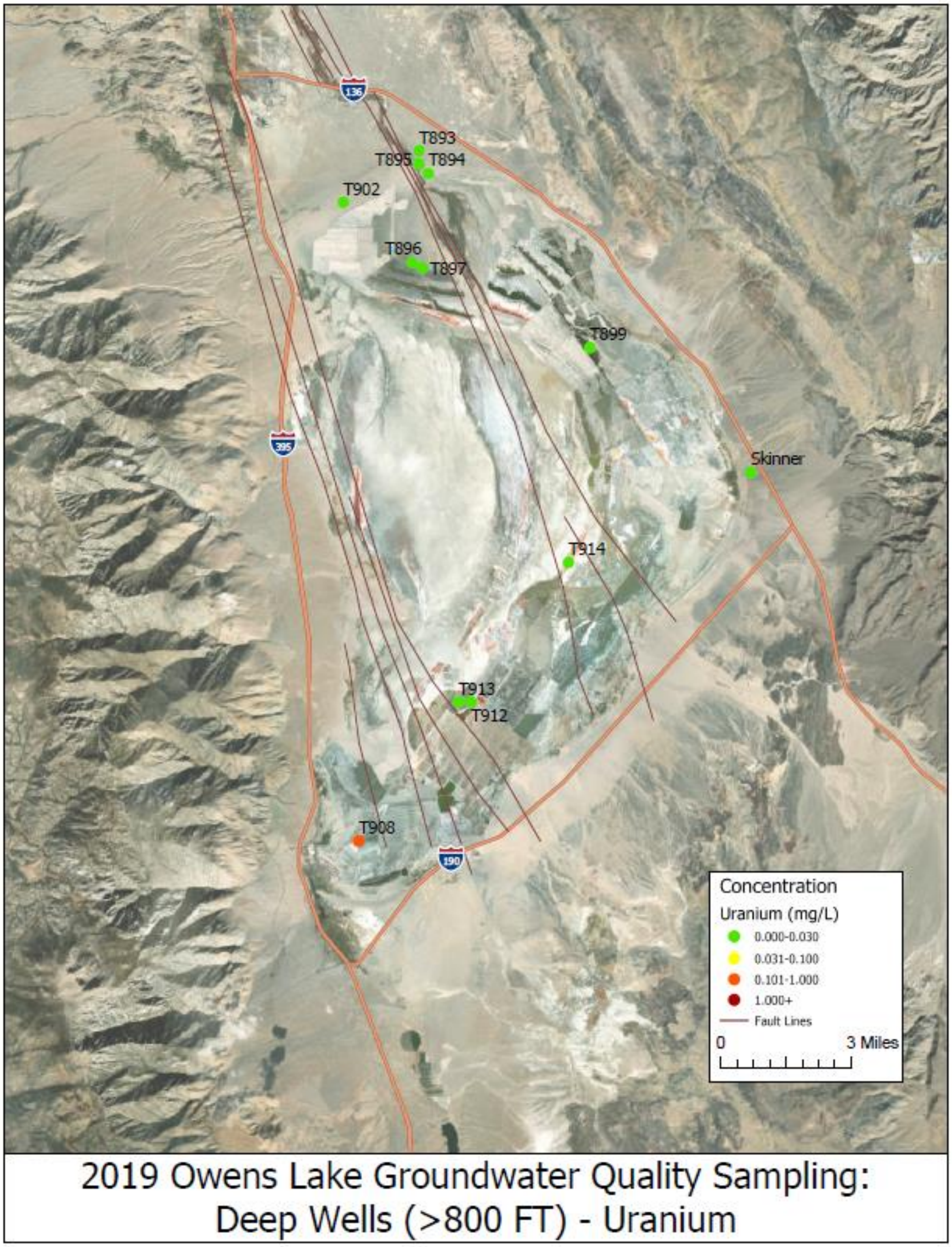


Figure B12: Map showing the concentrations of uranium in deep wells

Appendix C - Tables

Table C1: Depths, screening, diameters, and hydrologic readings of sites if available

Well	Diameter (in)	TD (ft)	Top of Screen (bgs)	Bottom of Screen (ft)	Distance to Water (ft) *positive denotes artesian head
T922	4	133	98	128	-90.96
T920	4	253	218	248	-211.78
MW4_S	4	165	140	160	-58.89
MW4_D	4	595	530	590	-49.08
T925	4	78	43	73	5.54
T926	4	98	63	93	266.75
T924	4	183	148	178	319.89
T858	2	27.5			-4.82
P4 A - Deep	2	32.5	30.5	32.5	15.46
T921	4	263	228	258	-230.7
T930	4	73	38	68	80.73
T931	4	62	27	57	-15.28
T929	4	93	58	88	-10.46
VDA 03	3	25	10	20	-12.20
Keeler Landfill Monitoring Well 1	2	25	15	25	-10.64
T919	4	73	38	68	-18.92
T928	4	93	58	88	-29.08
P2 A - Deep	2	32	29.5	31.5	-1.73
T348	8	80			-7.82
P1 A - Deep	2	32	29.5	31.5	-1.82
P7 A - Deep	2	32.5	30.5	32.5	-7.30
P6 A - Deep	2	32.5	30	32	64.85
P3 A - Deep	2	33	30	32	-1.54
T923	4	113	78	108	-70.06
VDA 15	3	35	20	30	-18.8
L9(1)	2	11	9	10	-3.13
P5 A - Deep					-1.69
K10(1)	2	11	9	10	-3.95
J10(1)	2	11	9	10	-1.51
T927					-31.63
P5a A - Deep					-1.69
VDA 14	3	35	20	30	-16.24
M8(1)	2	11	9	10	-0.05
T918					-21.6
P5(1)	2	11	9	10	
N7(3)	2	11	9	10	-2.01
KEELER(1)	2	11	9	10	-1.48

Well	Diameter (in)	TD (ft)	Top of Screen (bgs)	Bottom of Screen (ft)	Distance to Water (ft) *positive denotes artesian head
S3(3)	2	11	9	10	-4.15
C5(2)	2	5	3	4	-2.08
I10(5)	2	5	3	4	-1.75
FW Aggregates Well NQ-2	8	385	165	375	-44.5
FW Aggregates Well NP-1	8	360	65	355	-56.15
T892	4	390	290	370	-27.73
T891	4	540	480	520	-25.42
Down Valley Fault South		450	205	440	
T890	4	1500	1150	1230	-25.87
T910	4	260	200	240	65.20
T909	4	800	740	780	95.96
T904	4	380	300	360	4.57
T900	4	720	660	700	103.31
T898	4	340	240	320	108.31
T907	4	330	250	310	-61.49
T901	4	190	150	170	86.44
T913	4	1500	1420	1460	105.22
Riversite Monitoring Well Shallow	2	230	170	200	90.59
Riversite Monitoring Well Deep	2	515	485	505	103.79
Skinner Well	6				-45.03
Star Trek Monitoring Well					-51.17
USGS Monitoring Well					-49.73
Swansea Domestic Well					-13.10
Mill Site	2	260	220	240	-11.69
Keeler-Swansea Well	2	135	100	120	-8.80
MW5_I	4	465	400	460	121.93
MW5_S	2	245	200	240	7.18
MW5_D	4	665	600	660	122.14
P8 A - Deep	2	32.1	30.5	32.5	-1.70
Sulfate Domestic Monitoring Well					-84.70
Fault Test Well T6					62.15
T894	4	1270	1170	1250	71.80
T899	4	1003	920	960	103.99
T895	4	960	860	940	72.67
T893	4	1530	1430	1530	70.37
T896	4	1601	1280	1360	124.06
T902	4	1500	1290	1350	1.75
T903	4	800	720	780	7.45
T908	4	1470	1360	1470	106.08
T897	4	880	780	860	130.13
T914	4	1500	1360	1400	109.21

Well	Diameter (in)	TD (ft)	Top of Screen (bgs)	Bottom of Screen (ft)		Distance to Water (ft) *positive denotes artesian head
South FIP Monitoring Well	5.5	826	700	820	120	50.92
South FIP Production Well	12.75	820	700	810	110	51.17
TW-E	12	1495	620	1490	870	44.54
TW-W	12	845	440	840	400	53.13
Odell						-65.88

Table C2: Flow rates for flume sites in gallons per minute (gpm)

Flume Sites	Flowrate (gpm)
Whiskey Springs	1.15
Sulfate	327.30
Lizard Tail	1.49
Cottonwood Polymer Plant	200

Table C3: All available field parameter results from water quality sampling

Well	Specifc Conductance (µS/cm)	Temperature (°C)	pH
Boulder Cr. RV Park	672	22.9	7.52
C5(2)	66000	28.6	9.76
Cartego Mutual	193		7.82
Cottonwood Polymer Plant	200	14	7.11
Cottonwood Well	6068	18.7	9.07
Grace Mortensen	622	24.4	7.31
I10(5)	102100	23.9	9.46
J10(1)	6560	19.4	9.4
Jeff Mills Well	387	18.9	7.76
K10(1)	5810	23.6	8.36
Keeler CSD	1350		7.6
KEELER(1)	79500	20.5	9.79
L9(1)	5970	21.2	8.05
M8(1)	9670	21.1	8.67
Mt. View Trailer Park			6.65
MW4_D	375	19.1	9.51
MW4_S	322	20.3	9.34
MW5_S	13050	23.4	7.98

Well	Specifc Conductance (µS/cm)	Temperature (°C)	pH
N7(3)	43100	23.3	9.43
P1 A - Deep	1954	21.7	9.45
P2 A - Deep	2280	21.8	8.04
P3 A - Deep	3450	23.5	9.19
P4 A - Deep	266	19.7	7.86
P5 A - Deep	5680	22.6	7.39
P5(1)	23100	29.3	9.34
P5a A - Deep Trucksticker	7340	25.2	8.31
P6 A - Deep	3340	25.1	8.76
P7 A - Deep	2940	19.8	8.61
Rio Tinto	218	18.3	8.05
Riversite Monitoring Well	601	18.7	8.14
S3(3)	75100	23.8	9.45
T348	2320	22.1	7.25
T858	436	19.8	7.42
T890	1287	21	8.52
T891	682	20.2	9
T892	350	21.1	8.49
T901	3060	21.2	9.07
T911	8810	28.9	7.3
T918	12450	20.3	7.52
T919	2058	20.5	10.42
T920	232	21.1	6.91
T921	727	23.4	8.08
T922	199	19.1	8.05
T923	5390	28.1	6.92
T924	366	22.6	7.9
T925	336	26.9	8.15
T926	445	19	7.48
T927	7180	27	7.37
T928	2133	26.6	8.49
T929	1185	23.8	7.69
T930	661	21	7.77
T931	888	18.9	7.58
VDA 03	1317	19.7	7.35
VDA 10	1448	22.2	7.8
VDA 14	7690	22.8	6.85
VDA 15	5430	22.4	7.61
Whiskey Springs	8660	20.5	7.3
Bartlett	343	8.8	
Down Valley Fault South	539	18.4	7.53

Well	Specifc Conductance (µS/cm)	Temperature (°C)	pH
Fault Test Well T6	2420	21.3	8.76
Keeler-Swansea Well Shallow	2550	23.8	7.78
Lizard Tail Spring (C4)	1285	24.1	7.74
Mill Site	4050	23.5	8.94
MW5_D		19	8.83
MW5_I		16.7	9.32
P8 A - Deep	2730	25.6	7.6
PPG Well	3100	21.2	8.88
Riversite Monitoring Well	1098	18.5	8.28
Skinner Well	1645	25.5	8.75
Star Trek Monitoring Well	2860	20.3	8.35
Sulfate Domestic Monitoring	5950	22.3	8.59
Sulfate	3290	26.5	8.47
Swansea Domestic Well	1347	21.7	8.12
T898	1115	22.7	9.11
T900	977	20.9	8.58
T904	766	21.4	8.29
T907	2660	19.9	8.78
T909	400	22.5	9.15
T910	335	31.5	10.05
T913	25300	21.1	8.78
USGS Monitoring Well	17690	20.7	8.91
South FIP Monitoring Well	8050	20.4	8.21
South FIP Production Well	7340	20.2	8.24
T893	1065	27.4	9.24
T894	496	22.1	9.66
T895	998	20.8	9.27
T896	1087	29	9.19
T897	1480	21.6	9.06
T899	860	26.9	9.79
T902	1199	21.8	9.17
T903	1383	22.1	8.18
T908	1279	19.9	9
T912	6030	34.7	7.64
T914	3760	20.3	9.7
T915	7070	28.5	9.5
Odell	330	12.2	7.95
TW-E		21.3	7.46
TW-W		18.3	9.02