Luhdorff & Scalmanini
Consulting Engineers

Technical Memorandum

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SUBJECT: **GROUNDWATER AVAILABILITY AND IMPACT ANALYSIS (PVL LIME PLANT DEVELOPMENT PROJECT, APN: 0485-031-12)**

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1 INTRODUCTION

This Technical Memorandum (TM) describes the process used to determine groundwater availability and evaluate potential impacts of operating a new planned industrial well on existing groundwater users in the area. Provided herein are the key findings, conclusions, and preliminary recommendations regarding water availability for the proposed PVL processing plant in Trona, California (Project).

Implementation of the Project will utilize water from two sources. For drinking water, the Project proposed to obtain an estimated 1.3 gallons per minute (gpm) or 2.2 acre-feet per year (AF/year) of potable water from Searles Domestic Water Company (SDMC). The second source of water will be supplied by an onsite well that will be drilled to meet operational requirements. To meet operational requirements, the new planned well will need to produce a maximum of 30 gpm (49 AF/year). Based on engineering estimates provided by PVL, process water demand will be about 24 gpm (39 AF/year) with 6 gpm (10 AF/year) being discharged after treatment to an onsite detention pond where it will percolate or evaporate.

2 GEOLOGY AND HYDROGEOLOGY

Searles Valley is a north-trending structural valley that is bound by the Argus Range on the west and north and by the Slate Range on the north and east. The Garlock Fault is generally recognized as the southern limit of the groundwater basin, however topographically, the surface water drainage area of the valley continues south of the Garlock fault. The area of the Searles Valley drainage basin is estimated to be about 693 square miles.

There are three primary hydrogeologic units within the Searles Valley, alluvial deposits, saline deposits and bedrock complex. The alluvial deposits are loosely to moderately lithified clay, silt, sand, gravel and boulders. Near the basin margins, the alluvial deposits consist of sand, gravel and boulders. Toward the center, the coarse-grained facies grades into finer grained silts and clay beds.

The saline deposits are a sequence of interbedded mud and soluble evaporites that grade laterally to the surrounding alluvial deposits. When saturated, saline deposits yield large quantities of brine to wells. The Bedrock complex underlies the alluvial deposits and is composed of granitic, metamorphic, sedimentary and volcanic rock. Two wells have been drilled into the southwestern portion of the valley and have yielded some water from the bedrock complex. Additional evidence of water within the bedrock complex is a series of springs located in the Argus Range. Some areas within the bedrock complex are heavily fractured thus allowing for underflow from Indian Wells Valley to Searles Valley.

Natural recharge to the basin is presumably from three sources, percolation of runoff, subsurface inflow in unconsolidated sediments and direct infiltration from rain. Analyses of groundwater from the basin indicate that dissolved solids range from 5,000 milligrams per liter (mg/L) on the edge of the late to more than 350,000 mg/L in the center. Groundwater from wells in the vicinity of Searless Lake is inferior for essentially all beneficial users. Due to this poor water quality, all domestic water in Searless Valley is piped in from wells in Indian Well Valley.

3 GROUNDWATER CONDITIONS

3.1 Well Inventory

An inventory of existing industrial and monitoring wells within 1 mile of the PVL project was conducted by LSCE. Locations of these existing wells are presented on **Figure 1**.

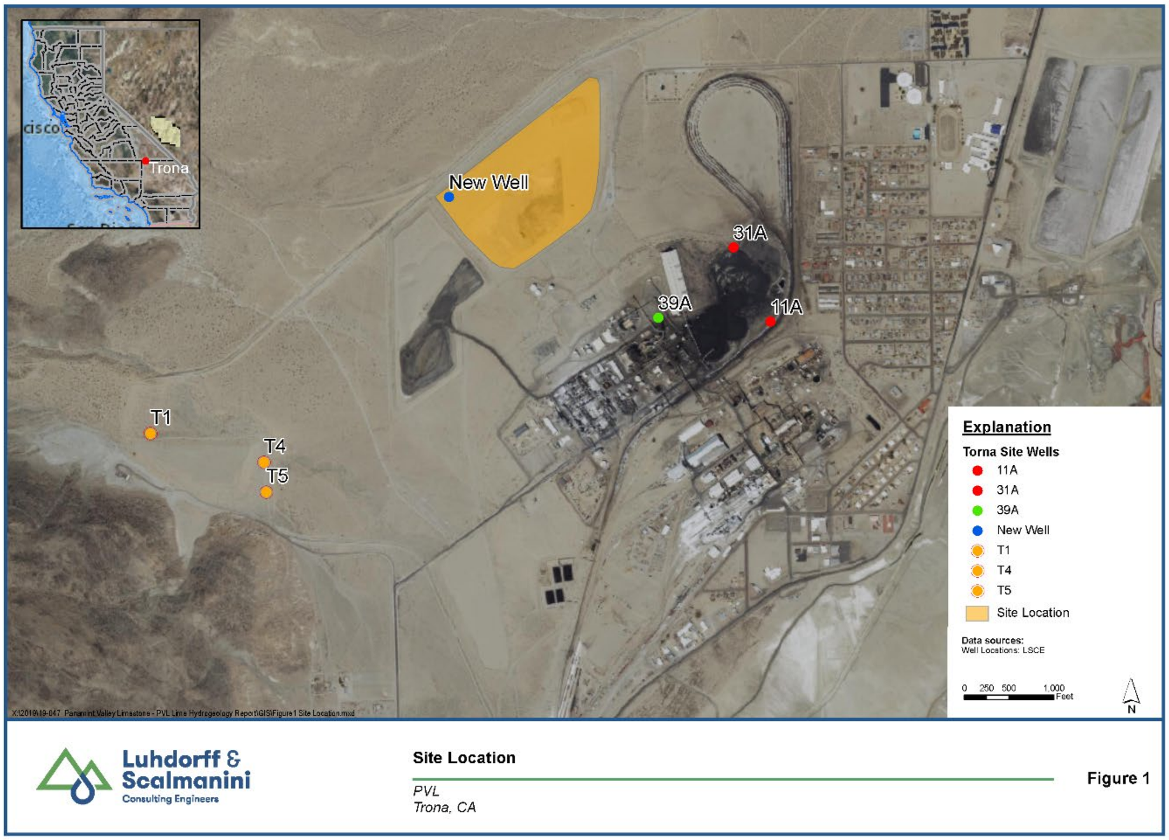


Figure 1: Proposed New Well and Nearby Industrial (39A, 31A and 11A) and Monitoring Wells (T1-T3)

3.2 Water Level Mapping

Water level mapping was conducted using water level data from nearby wells. The most recent data is from monitoring well located on the Trona-Argus Sanitary Landfill which is located approximately ½ mile west of the Project. **Figure 2** illustrates the groundwater flow direction and gradient from the landfill site. As illustrated on **Figure 2**, groundwater flow is generally to the northeast across the area. Based on the most recent data collected in 2016, the horizontal gradient in the area ranges from 0.08 ft per foot (ft/ft) to 0.12 ft/ft.

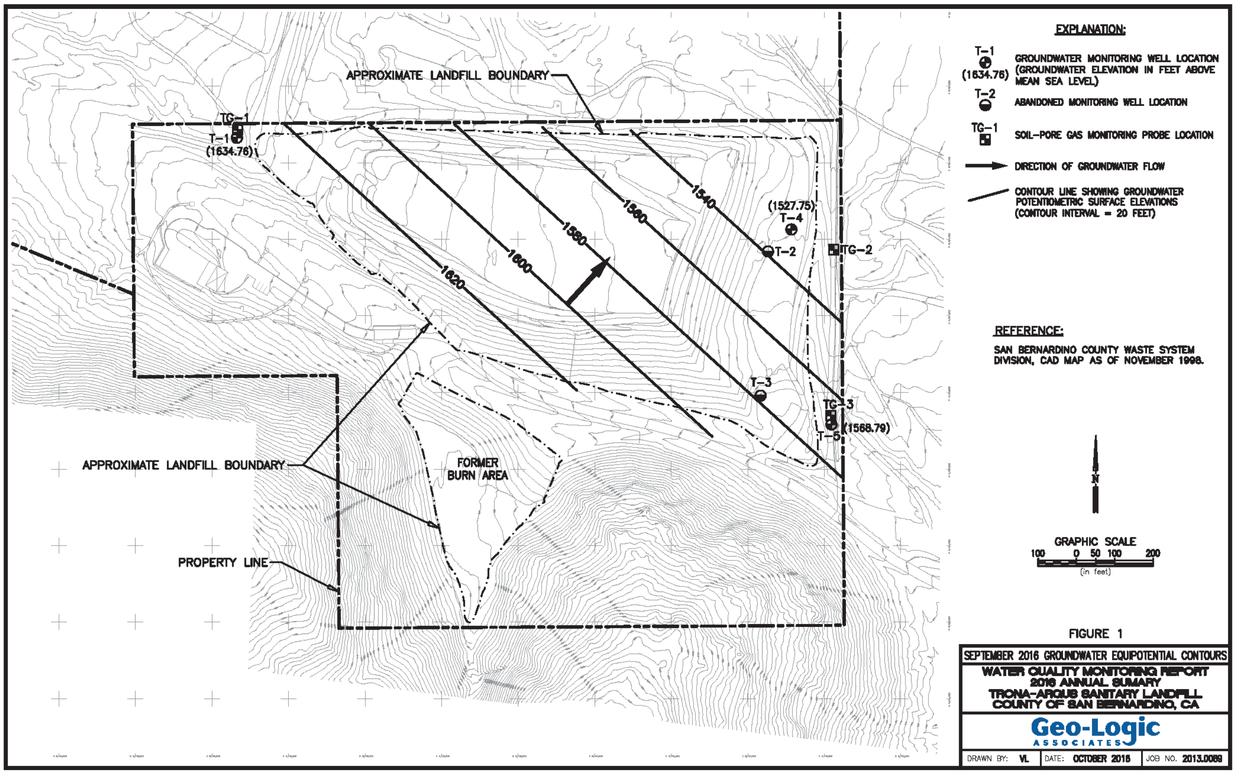


Figure 2: Equipotential contours and direction of the groundwater flow (Geo-Logic Associates, 2016)

3.3 Historical Water Level Changes

Limited historical water level data were available for the area. A hydrograph from T-1, a nearby monitoring well on the Trona-Argus Landfill is presented on **Figure 3**. Well locations are shown on **Figure 1**. The hydrograph indicates a increase in groundwater levels (groundwater was rising) starting in 1992 through approximately 1994, when depth to groundwater ranged from 262 feet below ground surface (BGS) to 268 feet BGS. From 1994 until 2009 depth to groundwater increased from approximately 262 feet BGS to 267 feet BGS. Since about 2010, groundwater levels have been relatively stable.

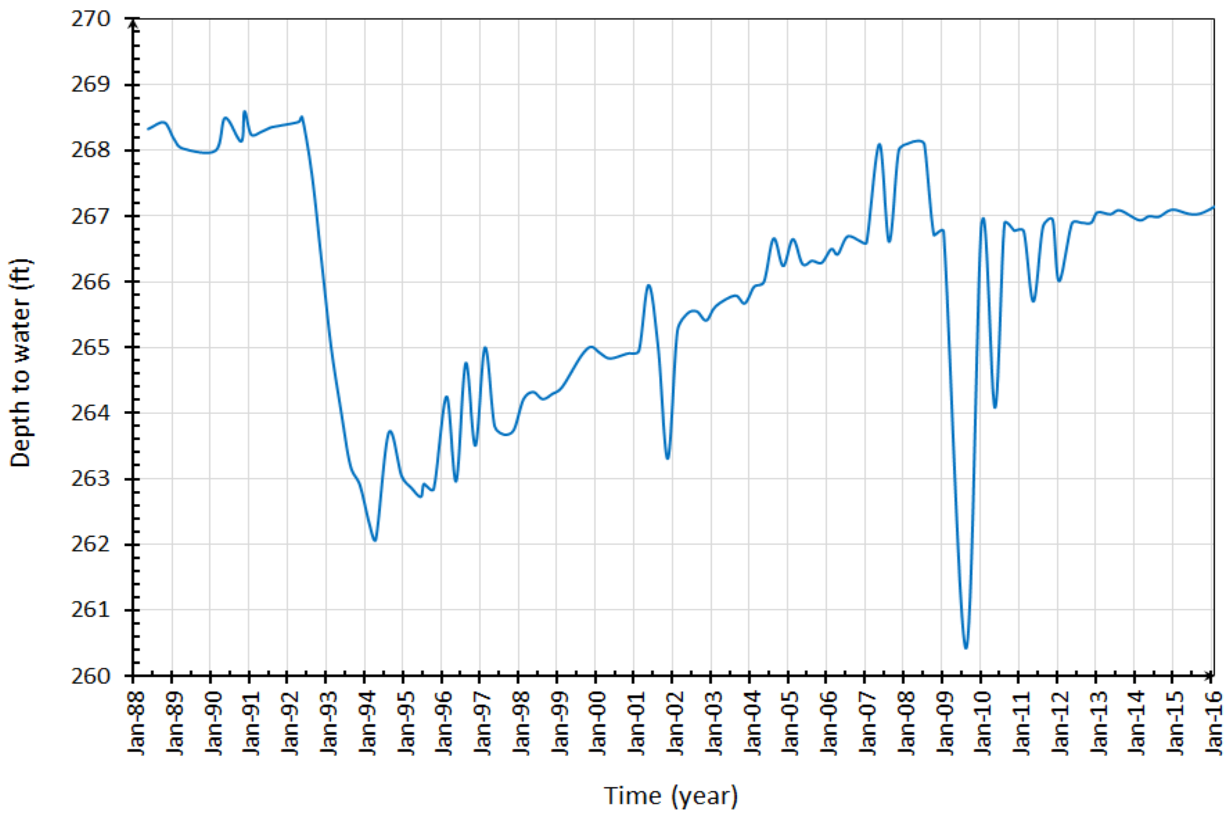


Figure 3: The hydrograph of depth to water at well T1

4 GROUNDWATER AVAILABILITY

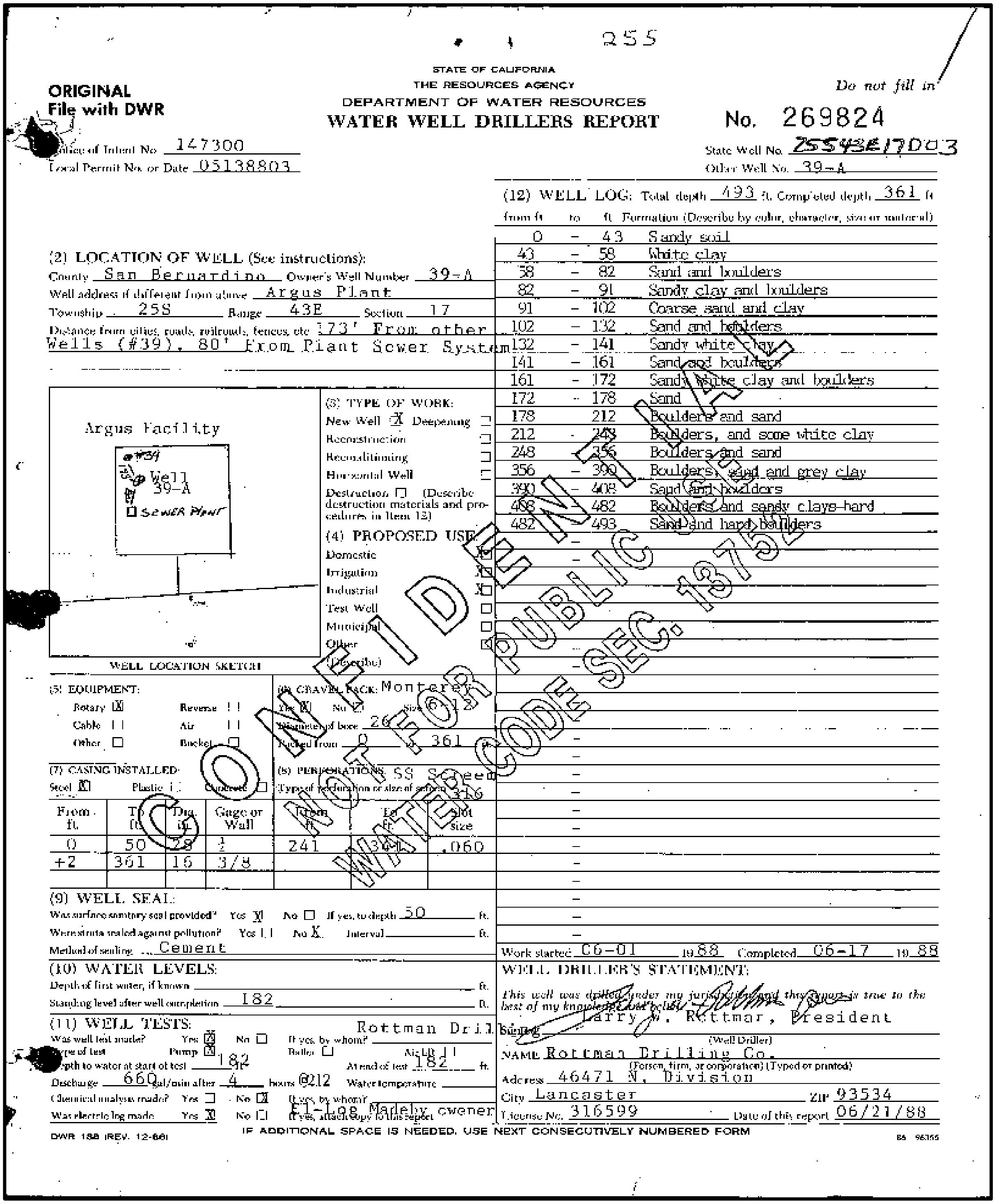
Two well-established and accepted methodologies were combined to evaluate groundwater availability for the Project. The first methodology evaluated the availability based on calculating the amount of groundwater flowing beneath the Project site. This groundwater would be available for extraction by one or more wells for use on the overlying lands. This evaluation was done by using Darcy's Law, which described flow through porous media. The second methodology quantified the groundwater resource by comparing the total amount of annual project usage to estimates of groundwater storage prepared by the California Department of Water Resources.

4.1 Availability based on Flowing Groundwater beneath the Project

Approximate groundwater discharge flowing through the PVL area was calculated from the 2016 seasonal groundwater elevation contours. These estimates were made utilizing Darcy's Law:

$$Q = KiA$$

Where *Q* is discharge (ft^3/day or AF/year), *K* is hydraulic conductivity (ft/day), *i* is the hydraulic horizontal gradient (ft/ft), and *A* (ft^2) is the cross-sectional area.



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ORIGINAL
File with DWR

STATE OF CALIFORNIA
THE RESOURCES AGENCY
DEPARTMENT OF WATER RESOURCES
WATER WELL DRILLERS REPORT

Do not fill in

No. 269824

Notice of Intent No. 147300
Local Permit No. or Date 05138803

State Well No. 25S43E17D03
Other Well No. 39-A

(12) WELL LOG: Total depth 493 ft. Completed depth 361 ft.

from ft.	to ft.	Formation (Describe by color, character, size or material)
0	43	Sandy soil
43	58	White clay
58	82	Sand and boulders
82	91	Sandy clay and boulders
91	102	Coarse sand and clay
102	132	Sand and boulders
132	141	Sandy white clay
141	161	Sand and boulders
161	172	Sandy white clay and boulders
172	178	Sand
178	212	Boulders and sand
212	248	Boulders, and some white clay
248	356	Boulders and sand
356	390	Boulders, sand and grey clay
390	408	Sand and boulders
408	482	Boulders and sandy clays-hard
482	493	Sand and hard boulders

(2) LOCATION OF WELL (See instructions):
County San Bernardino Owner's Well Number 39-A
Well address if different from above Argus Plant
Township 25S Range 43E Section 17
Distance from cities, roads, railroads, fences, etc. 173' From other Wells (#39), 80' From Plant Sewer System

Argus Facility
#34
Well 39-A
Sewer Plant

WELL LOCATION SKETCH

(3) TYPE OF WORK:
New Well X Deepening ☐
Reconstruction ☐
Reconditioning ☐
Horizontal Well ☐
Destruction ☐ (Describe destruction materials and procedures in Item 12)

(4) PROPOSED USE:
Domestic ☒
Irrigation ☒
Industrial ☒
Test Well ☐
Municipal ☐
Other ☒
(Describe)

(5) EQUIPMENT:
Rotary ☒ Reverse ☐
Cable ☐ Air ☐
Other ☐ Bucket ☐

(6) GRAVEL PACK: Monterey
Yes ☒ No ☐ Size 6-12
Diameter of bore 26
Packed from 0 to 361

(7) CASING INSTALLED:
Steel ☒ Plastic ☐ Concrete ☐

From ft.	To ft.	Dia. in.	Gage or Wall
0	50	28	1/4
+2	361	16	3/8

(8) PERFORATIONS: SS Screen
Type of perforation or size of screen 316

From ft.	To ft.	Slot size
241	341	.060

(9) WELL SEAL:
Was surface sanitary seal provided? Yes ☒ No ☐ If yes, to depth 50 ft.
Were strata sealed against pollution? Yes ☐ No X Interval ft.
Method of sealing Cement

(10) WATER LEVELS:
Depth of first water, if known ft.
Standing level after well completion 182 ft.

(11) WELL TESTS:
Was well test made? Yes ☒ No ☐ If yes, by whom? Rottman Drilling
Type of test Pump ☒ Bailer ☐ Air lift ☐
Depth to water at start of test 182 ft. At end of test 182 ft.
Discharge 660 gal/min after 4 hours @212 Water temperature
Chemical analysis made? Yes ☐ No ☒ If yes, by whom?
Was electric log made? Yes ☒ No ☐ If yes, attach copy to this report El-Log Madeby owener

Work started 06-01 1988 Completed 06-17 1988

WELL DRILLER'S STATEMENT:
This well was drilled under my jurisdiction and this report is true to the best of my knowledge and belief.
Signed Larry W. Rottmar, President
(Well Driller)
NAME Rottman Drilling Co.
(Person, firm, or corporation) (Typed or printed)
Address 46471 N. Division
City Lancaster ZIP 93534
License No. 316599 Date of this report 06/21/88

DWR 188 (REV. 12-68)
IF ADDITIONAL SPACE IS NEEDED, USE NEXT CONSECUTIVELY NUMBERED FORM

CONFIDENTIAL
NOT FOR PUBLIC
WATER CODE SEC. 13752

Figure 4: Well completion report for Well 39A (WCR, 1988)

Hydraulic Conductivity, K: Values for transmissivity, T, were reviewed from well testing conducted on Well 39A, as documented in well completion report shown on **Figure 4**. Aquifer transmissivity is ideally determined from aquifer tests, but these have not been done in the vicinity. In the absence of aquifer tests, specific capacity valued can be used to estimate transmissivity. During well testing in 1988, a specific capacity (SC) of 22 gpm per foot of drawdown was calculated. Applying a commonly used conversion factor for semi-confined aquifers of 1,500, the estimated transmissivity would be 4,412 ft^2/day. To calculate hydraulic conductivity, K, LSCE used the equation:

$$T = Kb$$

Where b is the aquifer thickness. The derivation of aquifer thickness is described in detail below. For this analysis, an aquifer thickness of 311 feet was used to calculate K. This results in a K of 14 ft/day.

Hydraulic Gradient, i: Range of hydraulic gradient (i) value was 0.08 to 0.12 (ft/ft) from Geo-Logic Associate (2016).

Cross-Section Area, A: The cross-sectional area of the aquifer (A) was determined based on utilizing the saturated thickness across the width of the aquifer that would be available to the proposed well.

Aquifer Width: The aquifer width utilized for this calculation is 2,500 ft.

Aquifer Thickness: Well 39A was drilled to a depth of 493 ft based on the drillers log and the bottom of the well is still within the alluvial aquifer. With a depth to water of 182 ft, this results in a saturated aquifer thickness of 311 ft. No other industrial well logs were available in this area.

Quantity of Groundwater Flow, Q: The calculated values of Q ranged from 20 AF/day to 30 AF/day. The anticipated groundwater demand for site development and future operations is 0.13 AF/day (49 AF/year). On this basis, sufficient groundwater is available to supply the PVL project.

4.2 Availability based on Groundwater Balance

DWR estimated that the groundwater storage capacity of the Valley is approximately 2,140,000 AF (DWR, 2004). The annual project use is 49 AF which is less than 0.003 percent of the groundwater storage capacity.

5 IMPACTS OF PROPOSED PUMPING

To assess the extent and degree of groundwater drawdown in response to Project extraction at 30 gpm, a drawdown analysis was conducted. The impact analysis is based on continuous pumping rate of 30 gpm on a 24-hour per day schedule for a 20-year period.

5.1 Analytical Approach

In order to estimate the amount of drawdown expected during long-term pumping, LSCE used an analytical model which incorporates the Neuman (1974) aquifer equation to determine the drawdown radially from a pumping well once the transmissivity (T) and storativity (S) values of the aquifer material have been determined. For reference, the transmissivity (T) is the rate at which water is transmitted through a unit width of the aquifer for its full thickness at a unit hydraulic gradient, usually in feet squared per day. Storativity (S) is the ratio of the volume of water a rock or soil will yield to the volume of rock or soil, a dimensionless number. Q is the pumping rate in either AF/year or gpm (note: 1 AF equals 325,851 gallons).

The Neuman equation was developed based on the following assumptions (Fetter, 2001):

1. The aquifer is unconfined and homogeneous.
2. All flow is radial and horizontal toward the well.
3. The pumping well and observation wells are fully penetrating the aquifer.
4. The pumping well is 100% efficient.
5. All geologic formations are horizontal with infinite horizontal extent.
6. The potentiometric surface of the aquifer is horizontal and steady before starting to pump.
7. The vadose zone has no influence on the drawdown.
8. Initially pumped water comes from the instantaneous release of elastic storage water.
9. Eventually water comes from the storage due to gravity.
10. The drawdown is negligible compared with the saturated aquifer thickness.
11. The specific yield is at least 10 times greater than the elastic storativity.
12. Anisotropic hydraulic conductivity is an option.

The Neuman's solution is:

$$h_0 - h = \frac{Q}{4\pi T} W(u_A, u_B, \Gamma)$$

With:

$$u_A = \frac{r^2 S}{4Tt} \quad (Type\ curve\ for\ early\ drawdown\ data)$$

$$u_B = \frac{r^2 S_y}{4Tt} \quad (Type\ curve\ for\ later\ drawdown\ data)$$

$$\Gamma = \frac{r^2 K_v}{b^2 K_r}$$

Where, $W(u_A, u_B, \Gamma)$ is the well function (tabulated in the literature), $h_0 - h$ is the drawdown [L], Q is the pumping rate of the well [L^3 /T], T is the transmissivity [L^2 /T], r is the radial distance from the pumping well [L], S is the storativity (dimensionless), S_y is the specific yield (dimensionless), t is the time [T], K_r is the horizontal hydraulic conductivity [L/T], K_v is the vertical hydraulic conductivity [L/T], and b is the initial saturated thickness of the aquifer [L].

Parameters used for the Neuman calculation are listed in **Table 1** and change of drawdown due to the operation of the new well in the area is shown in **Figures 5 and 6**.

Table 1: Neuman Parameters

Parameter	Units	Value	Reference
Q	[ft3/d]	5775	Panamint Valley Limestone, INC. (Q = 30 gpm = 5775 cfd)
T	[ft2/d]	4412	Calculated from specific capacity (WCR, 1988)
S_y	[ ]	0.15	Indian Wells Valley Groundwater Basin (DWR, 2004-IWVGB)
b	[ft]	311	Calculated using depth of well (= 493 ft) and depth to water (= 182 ft) from WCR (Well39A)
Kv/Kr	[ ]	0.1	Todd (1980)
n	[ ]	0.25	Geo-Logic Associate (2016)
S	[ ]	0.0094	$S = \rho g(\alpha + n\beta)b$, where $\rho =$ density of water = 1000 kg/m^3 $g =$ gravitational acceleration = 9.8 m/s^2 $\alpha =$ aquifer compressibility = 10-8 m^2/N $n =$ porosity = 0.25 $\beta =$ water compressibility = 4.4e-10 m^2/N $b =$ aquifer thickness = 311 ft = 95 m

As a result of the continuous extraction of water through the new well operation, a cone of depression occurs around the well with the highest amount of groundwater drawdown at the new well's location and less impact far from the well. **Figure 5** illustrates the amount of drawdown at different distances from the new well. For instance, at the distance of 2000 ft, groundwater table is lowered by 0.5 ft after 20 years of nonstop pumping of the new well. This drop of the water table occurs only in response to this well's operation while the current condition of the water table is the superposition (contribution) of all drawdowns due to all other pumping wells active in the area.

The lowering of the water table at a specific distance from the well also changes by time. **Figure 6** demonstrates this change for three different distances. For instance, at 2000 ft away from the new well, groundwater table starts to drop after 10 hours of pumping the new well and the drawdown after 20 years at the same location is less than 0.5 ft. The shape of the curves in **Figure 6** follows the Neuman (1974) calculations which encounters the effects of elastic storage at early times and specific yield at later time in the unconfined aquifer.

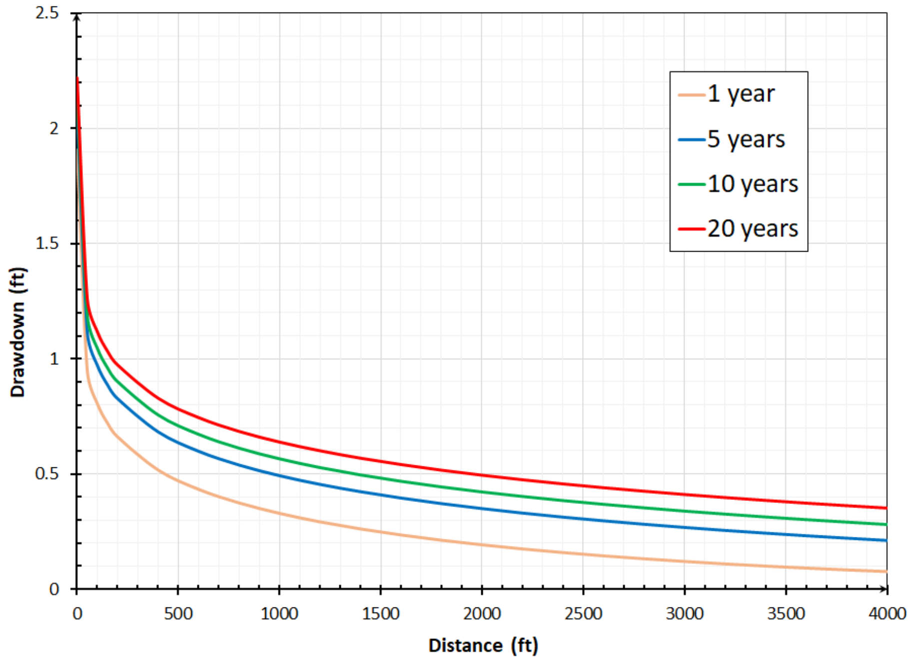

Figure 5: Change of drawdown due to the new well operation after different years of pumping

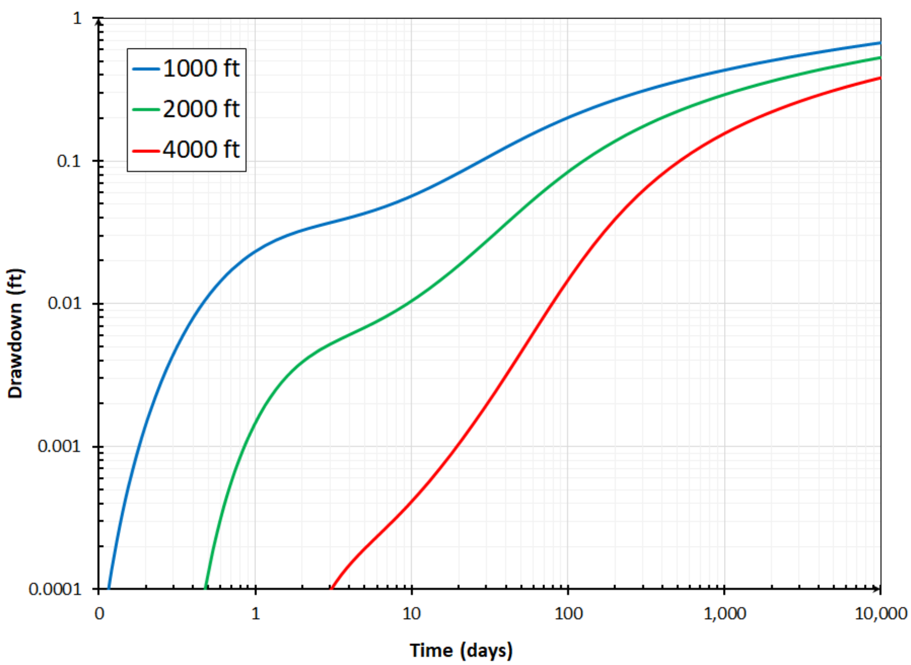

Figure 6: Change of drawdown at different distances due to the operation of the new pumping well

5.2 Area of Potential Impact

The results of this analysis indicate the drawdown of water table at the radius of approximately one mile from the well, after 20 years of continuous pumping at 30 gpm, is less than 6 inches. This is shown graphically on **Figure 7**.

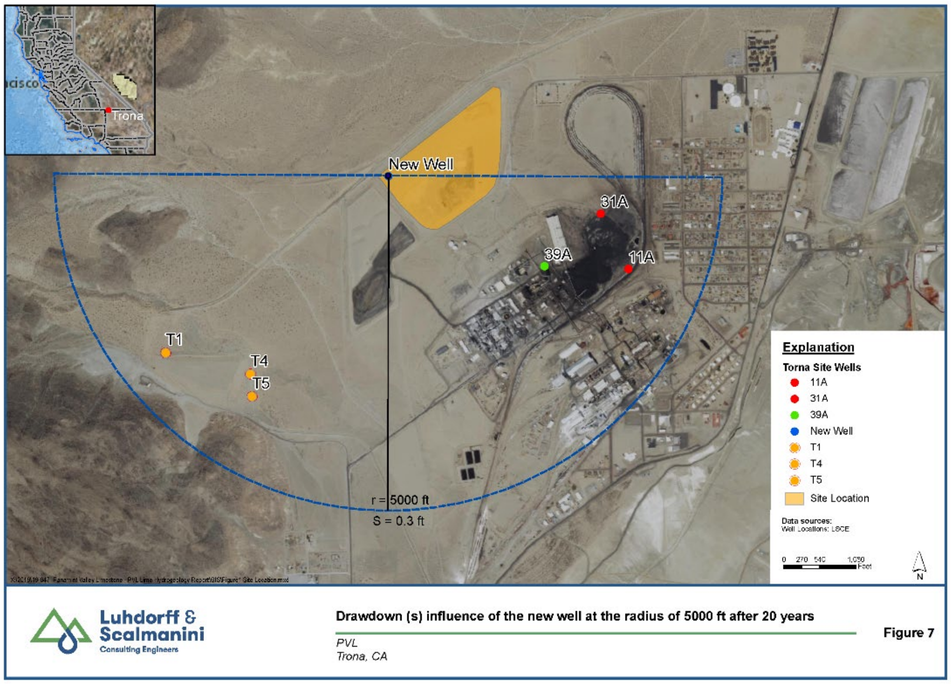

Figure 7: Simulated Drawdown after 20 years

6 CONCLUSIONS

Groundwater availability was calculated on the basis of Darcy's Law using available parameters from existing wells. The result of the groundwater analysis is that sufficient groundwater supplies exist and are quantified as being at least 7,000 AF/year (inflow) flowing beneath the Project Site, or stated differently, the Project site is located on lands overlying the groundwater supplies for which 7,000 AF/year (inflow) of groundwater exists. The proposed project will only utilize approximately 49 AF/year, or less than 1% of the total amount of groundwater flowing in this area. These calculations confirm that Project pumping of 49 AF/year from the local aquifer could be maintained by groundwater inflow.

Operating this well will have minimal impacts on nearby industrial wells. The predicted drawdown after 20 years of continuous pumping (assuming no recharge) is less than 6 inches at a radius of 5,000 feet. As a comparison, groundwater levels fluctuate seasonally more than 6 inches in this area.

Our evaluation of other professional engineering and hydrogeological analyses, coupled with LSCE's analysis of this Project site using accepted methodologies, results in calculations and conclusions that represent a conservative quantification of groundwater supplies available to the proposed Project, and more generally, the local vicinity.

7 LIMITATIONS

The conclusions presented in this report are professional opinions based solely upon the presented data. They are intended exclusively for the purpose outlined herein and the site location and Project indicated. This report is for the sole use and benefit of the Client. The scope of services performed in execution of this investigation may not be appropriate to satisfy the needs of other users, and any use or reuse of this document or the findings, conclusions, or recommendations presented herein is at the sole risk of said user.

Given that the scope of services for this investigation was limited, it is possible that currently unrecognized subsurface conditions may be present at the site. Should site use or conditions change, the information and conclusions in this report may no longer apply. Opinions relating to environmental, geologic, and geotechnical conditions are based on limited data and actual conditions may vary from those encountered at the times and locations where data were obtained. The effects of boundary mountains (barriers) at north-west side of the area are neglected in this study. No express or implied representation or warranty is included or intended in this report except that the work was performed within the limits prescribed by the Client with the customary thoroughness and competence of professionals working in the same area on similar projects.

8 REFERENCES

California Department of Water Resources (DWR), 2004, "California's Ground Water, Bulletin No. 118, Searles Valley Groundwater Basin (SVGB)."
https://water.ca.gov/LegacyFiles/pubs/groundwater/bulletin_118/basindescriptions/6-52.pdf

California Department of Water Resources (DWR), 2004, "California's Ground Water, Bulletin No. 118, Indian Wells Valley Groundwater Basin (IWVGB)."
https://water.ca.gov/LegacyFiles/groundwater/bulletin118/basindescriptions/6-54.pdf

Fetter, C.W., 2001, "Applied hydrogeology," 4th ed., Prentice Hall, New Jersey, 598p.

Geo-Logic Associate, 2016, "Water Quality Monitoring Report, 2016 Annual Summary Report, Trona-Argus Sanitary Landfill," prepared for County of San Bernardino Solid Waste Management Department, November.

Neuman, S.P., 1974, "Effect of partial penetration on flow in unconfined aquifers considering delayed gravity response, Water Resources Research," vol. 10, no. 2, pp. 303-312.

Todd, D.K., 1980, "Groundwater hydrology," 2nd ed., John Wiley and Sons, New York, 535p.

Well Completion Report (WCR), 1988, "Water Well Drillers Report, No. 269824," Department of Water Resources, Well39A, June 198