Preliminary and Interpretive Commentary
Proposed Water Well Target Locations
by
David W. Abbott, PG, CHg and www.Surveying4Water.com

Date: September 24, 2022

To:

Re: Reconnaissance-level Hydrogeologic Survey for the property,

1. INTRODUCTION

Surveying4Water.Com in association with David W. Abbott, a Professional Geologist (PG)[1] and a Certified Hydrogeologist (CHg) in the State of California, is pleased to present this Preliminary and Interpretive Commentary to convey the results of the recent reconnaissance-level (recon-level) hydrogeologic survey that was performed on your property according to the terms of our agreement signed on September 13, 2022. This *reconnaissance survey*[2] provides a rapid geologic and hydrogeologic survey which was made to gain a broad and general knowledge of the geology and hydrogeology of the region. The results of this survey are derived from a hydrogeological analysis and from instrumentation including the general selection and locations of possible sites and estimated target depths for a proposed water supply well on your property.

The rural/agriculture property (≈ 4.8-acres) is located at 11106 South Jenny Road, Yucca, AZ and is in Section 25Cd, Township 18 South, Range 17 West of the Gila and Salt River (G/S River) Base and Meridian on the Yucca NE, AZ– Mohave County, 7.5-minute series USGS topographic (topo) quadrangle map (1970 edition) at an elevation (elev.) of ≈ 2,720 feet (ft) above mean sea level (amsl) and shown on Figure 1 – Location Map and Figure 2 – Google Earth and Profile Plot Sketch Map. The property is located on the proximal portion (upper part) of a western-sloping alluvial fan which drains into the Sacramento Valley Wash at elev. ranging between ≈ 1,720 and 1,800 ft amsl. The Sacramento Wash is a tributary to the Colorado River (elev. ≈ 470 ft amsl and ≈ 27 mi southwest of the property. The average rainfall (1980 to 2010) is ≈ 10- to 15-inches per year (PRISM Climate Group, Oregon State University, 2014). The Registry of Wells in Arizona (Wells 55) shows 8 wells installed in Section 35. According to the Registry of Wells website of the Arizona Department of Water Resources (ADWR), there are 8 (6 with available data) Well Driller Reports (ADWR) and Logs

[1] A list of Acronyms and Abbreviations are in Section 11.
[2] Words in italics are defined using either the *Glossary of Geology* (5th edition, 2005) or the *Glossary of Hydrology* (1998) both are published by the American Geological Institute; or other references.

(form DWR55-55) available for Section 35 (1 mi^2) with depths ranging between 420 and 1,005; averaging 693 ft; the reported water levels range between 292 to 590 ft below ground surface.

Surveying4Water.Com performed an initial recon-level hydrogeologic and passive Very Low Frequency (VLF) Electromagnetic (EM) survey on this property. A VLF-EM survey is one of several possible exploration techniques to determine subsurface characteristics and geologic structures. The survey was conducted with a Receiver which measures the changes in the EM currents along traverses. The survey yields *a* current density *profile* which is a graph or drawing that shows the variations of one property such as elev. or EM, usually on the y-axis, with respect to another property, usually distance along the ground surface on the x-axis.

EM is an *electromagnetic exploration method* based on the measurement of alternating magnetic fields (AMF) associated with artificial or natural currents occurring in the subsurface. If these currents are induced by a primary AMF, the name *inductive EM method* applies. If these currents are conducted into the ground via electrodes, the name *conductive EM method* applies. The VLF-EM method used here is an inductive survey method.

The VLF-EM method measures the induced currents produced by local subsurface features including the general distribution and properties of the geologic structure, joints and cracks, faults, and rock beneath the property. The induced currents are generated from the prevailing and transmitted current originating from usually distant and powerful AMF transmitters operated by the US Navy for submarine vessel communications. These subsurface features are inferred from the VLF-EM data, can be related to the possible occurrences and accessibility of groundwater (GW), and can help to select a more favorable drilling location for a water supply well. No direct or physical contact of the underlying geology or other subsurface exploration methods (i.e., bore hole or test well drilling or fracture trace analysis) were performed for this recon. The findings and conclusions of this survey are based on research of readily available local geologic and hydrogeologic data coupled with instrumentation (Receiver) which measures the primary and induced (or secondary-type) currents by the induction method with computer-generated and -enhanced graphics interface provided with the Receiver; and with similar past experience, type, and scaled (2- to 45-acres) projects.

2. FIELD WORK

Surveying4Water.Com visited the property and selected accessible and suitable areas for the surveys. Using ground surface and passive methods, the handheld Receiver measures and stores data sets of the primary and induced electrical parameters at each occupied station to reveal the inferred subsurface geology and structure from the induced AMF propagated by the US Navy transmitter. An occupied *station* is a position at which an observation is made along a traverse. A *traverse* is a sequence or system of measured lengths and directions of straight lines connecting a series of surveyed stations (or points) on the Earth's surface, obtained by or from field measurements, and is used in determining the relative positions of the stations. The survey was conducted along roughly linear traverses on the property that were generally perpendicular to the regional geologic trends (geomorphic and/or structural, if known).

The field data for each station is concurrently down-loaded (when a station is occupied) into the memory of the Receiver for computer analysis. The computer-generated analysis includes the profile(s) during the traverse. The subsurface pseudosections (charts) (Figures 3 through 7) are later generated on a home computer with software provided with the field instrument. A *pseudosection* (p-*section*) is used to present all of the data from a traverse in one chart; the p-section bears <u>no relationship</u> to a geologic cross section. The field technician is instructed to traverse perpendicular to topographic and geomorphic features (valleys, ground surface depressions, outcroppings, etc.). The approximate locations of the survey traverses and the stations along the profile are shown in various colors on Fig. 2; and identify the approximate starting point and the direction of the profiles with an arrow. Six traverses (totaling ≈ 595 meters or 1,950 ft) were performed on the property; 5 with a north-south trend and one with a northeast-southwest trend.

3. TECHNOLOGY

EM surveys are sometimes referred to as secondary-type exploration methods since there is no direct physical contact with the ground surface or subsurface geologic formations. The underlying geologic structure is inferred from the induced AMF caused by the US Navy transmitter and measured by the Receiver. If available, geologic information, geologic maps, and topo maps can help to interpret the surveys. Using state-of-the-art instrumentation and methodology, this non-invasive method is useful in the identification of the general structural features beneath the ground surface. The inferred geologic and structural features may include identification of fracture zones, joints, and cracks that disrupt the homogeneity of the otherwise homogenous subsurface rocks and can be useful in identifying optimum locations where GW may be present. Note that this method does not "find" GW. This method is especially useful where the property conditions, access, and project budgets make direct subsurface exploration with test wells costly or impractical.

Surveying4Water.Com performs VLF-EM surveys for its clients with the Receiver. Natural and manmade primary currents (waves) penetrate the rock formations underlying the ground surface. In rock formations which are homogeneous with respect to electrical conductivity (EC) and resistivity (R) (note that EC is the mathematical reciprocal of R), the primary current will continue to penetrate both laterally and with depth until the energy of the wave dissipates. If the primary current encounters a subsurface feature (such as water filled fractures or joints – also known as an electrical conductor) with a different R than the surrounding rocks, a new or secondary (*induced*) current develops and its wave energy will alter the primary wave energy of the transmission. The subsurface features identified by the induced current can be buried geologic features or manmade objects (i.e., pipelines, buried drums, septic tanks, leach fields, etc.).

In general, un-fractured rock has a greater R and is more dense and massive than fractured and jointed rocks which may contain greater moisture content or contain more water than the surrounding un-fractured rock. The secondary electrical currents generated from the fractured rock deviates from and are anomalous to the background measurements of the more homogeneous surrounding un-fractured rocks. The tentative locations of anomalies are recorded by Surveying4Water.Com with the Receiver which may suggest locations for additional investigations (i.e., test well drilling). An *anomaly* is a geological feature, especially in the subsurface, which is different from the general surroundings and possibly of potential economic value; like a VLF-EM anomaly. At the conclusion of the passive ground surface survey, this information is provided to the CHg for his review and additional research into the local geology and hydrogeology of the area.

The Receiver measures and records the primary and reflective (secondary currents produced by induction) at the stations along a given traverse. Five traverses were conducted across the ground surface of this property; the locations are shown on Fig. 2. The computer-enhanced and -analyzed data set from the transverses are graphically depicted on charts. The variation (percent difference between the primary and secondary currents) of the signals measured from the underlying rocks is shown with various shades of color as depicted on the charts.

A color bar scale (ranging from -25 to +30%) is provided with the charts (see Figs. 3 through 7). The colors on the left-hand side (cooler or colder) of the scale indicate that the rocks are more homogeneous (i.e., no fractures), while the right-hand side (warmer and hotter colors) of the bar scale suggests the underlying geology or structure are heterogeneous or anomalous in contrast to the surrounding un-fractured rocks. The observed hotter anomalies along the profile are inferred to be more favorable for the movement and storage of GW. The warmer colors indicate the degree to which the rocks may be fractured which could provide sufficient permeability for a water supply. For example red colors on the chart would indicate that the rock has a greater amount of fracturing than the yellows. Sometimes, charts are re-plotted with additional software; these transformations may allow further evaluation and enhanced analysis of the data.

Occasionally, anomalies shown on the charts are not well developed at properties underlain with crystalline igneous or metamorphic or sedimentary rocks. In general, crystalline rocks are formed beneath the ground surface from cooling of a hot magma or through metamorphism into a massive, hard, host rock; generally having fewer discontinuities, fractures, and joints. When discontinuities, fractures, or joints occur from thermal cooling, geologic processes, or tectonic activities they commonly do not have large openings or apertures; locating them with passive survey techniques becomes more difficult. Passive ground surface methods rely on fractured rock areas having properties (EC and R) differing from those of the host rocks. The electrical contrast between the host rock and the fractures is inferred from this survey.

It is clear that this data is subject to interpretation and the results obtained from this method are not unique. More importantly, these interpretations do not guarantee the presence of GW at profile anomalies; nor can the results provide data or information about the well yield (gallons per minute; gpm) or GW quality (salinity or Total Dissolved Solids) that may be found at the anomaly. However, typical fractured rock aquifers can provide reliable and sustainable yields to a well ranging between 3 and 30 gpm while using about 50 ft of drawdown; yields greater than 100 gpm are the anomaly rather than the norm for fractured rock water-bearing systems. A certain degree of risk occurs when using secondary-types of subsurface exploration. Drilling a test well is about the only way to identify and verify the characteristics and properties of underlying rocks and GW. However, the success rate (82%) for EM techniques is much greater than other geological techniques in identifying subsurface fractures which include logistical (50%); air photo interpretation (61%); and hydrogeology (66%); note that combining both EM and R (vertical electric soundings; VES) methods is 90% (Singhal and Gupta, 2010, page 305).

Despite the risks of EM exploration methods, Surveying4Water.Com has had success in locating water wells in environments that tap into fractured rock water-bearing systems. The VLF-EM system described here allows Surveying4Water.Com to access the subsurface geological characteristics (by inference) of a particular portion of the property in a rapid manner at a reasonable cost.

4. EQUIPMENT

Field measurements are collected along each individual traverse at approximately 30 to 50 ft intervals (stations). However, all computer-generated profiles are illustrated using length units of meters (m) rather than ft both in terms of linear distances and depths along the profile and p-section. The theoretical depth limitation for collection of meaningful data is about 330 ft (100 m) or greater in crystalline rock. One meter is equal to 3.28 ft; or one foot is equal to 0.305 m. Based on past projects and review of well drillers' logs, experience has shown that the depth of data collection for the profiles usually extends to at least 330 ft below the ground surface in crystalline rocks; less in sedimentary rocks.

In general, the greater the length of the traverse: the better the quality of the data because it encompasses more of the anomaly. Ideally, the length of a profile should cross an anomaly but many conditions limit the length of the profiling to one property-sized parcel. Some property conditions with the presence of manmade objects will restrict the lengths of the profiles and limit the length and access to portions of the property. Examples of property conditions that can impact the profiles are overhead and underground power wires, phone wires or buried metal conduits, metal fences, buildings, and other objects. These conditions are noted and accounted for during the survey. These cultural objects emit induced electrical currents that may affect the data from the VLF-EM survey.

At times, surveys will be conducted on adjacent properties (with the owners' permission), and as close as possible to manmade objects to allow analysis with respect to the continuity and extent of profile anomalies. As a result of the computer-generated data analysis and from experience, Surveying4Water.Com has identified potential well locations[s] (targets) with a flag placed in the ground where the Receiver interprets a potential location of fractures and/or permeable rocks.

The Receiver software cannot differentiate between ground surface elev. changes along a given traverse. All computer software generated profiles are assumed to be representative of nearly-level ground surface. Consequently, drilling depths on hillsides may tend to be deeper than drilling depths in relatively flat terrain.

5. FLAGGED MEASUREMENTS

Ground surface traverses are performed for the survey on the client's property to collect data on the inferred subsurface geologic and structural characteristics of the rocks underlying the property along each traverse. These data are stored in the computer that is used during the survey. While performing the traverses, the Receiver provides the operating technician information concerning the progress of each traverse and the analysis of the collected data. The technician sets a flag marked with numbers on the ground surface at prescribed stations. The number on the flag is used to identify the location on the ground surface along the traverse at the property and is linked to the corresponding location along the p-section. The number on the flag does not represent the distance shown on the p-section generated by the Receiver. The flag numbers do correlate with specific station numbers that are on the p-section which is created by the computer during the survey. The client must not confuse the numbers written on the flags along the traverses with station numbers, or other notations, on the charts.

The Receiver and internal algorithms convert the field data into m shown on the charts into a conventional 2-dimensional coordinate system of computer points which are numerically referenced on the flags that are placed on the ground along the traverse. Clients are responsible for keeping the flags in-place until a target location is selected and finalized by the CHg and identified in this Commentary. The CHg's analysis for the clients' property is based on data provided by the technician (and his worksheet) and research on the local geology and hydrogeology. The results are displayed in m along the top of the p-section; zero is usually to the left and represents the start of the traverse. The direction of the traverse is indicated by an arrow on the traverse lines of Fig. 2. The Interpretive Commentary that is presented in Sections 6 and 7 references the stations in m from the start of the traverse and the depths are in ft, respectively.

6. CONCLUSIONS AND RECOMMENDATIONS

The work that was completed on this property is based on the mathematical modeling, analysis from the computer, and review of geologic and topographic maps. This property appears primarily to be underlain by an unknown thickness of alluvium and beneath the alluvium is semi-fractured and fractured crystalline rock formation.

The property is located 0n the western flanks of the northwest-southeast trending Hualapai Mountains of Mohave County, AZ. The southern portions of the Hualapai Mountains are composed of two basic geologic units that consist of Pre-Cambrian-age granite and related crystalline rocks (gr) and granite gneiss (gn). Surrounding the Hualapai Mountains are Quaternary-age sand, gravel, and conglomerate (Qts). (Wilson, Elred D. and Richard T. Moore, 1959, Geologic Map of Mohave County, AZ, prepared by the Arizona Bureau of Mines, U. of Arizona, Tucson, AZ, Map) and (Richard, S. M., Reynolds, S.J., Spencer, J. E., and Pearthree, P. A., 2000, Geologic Map of Arizona: Arizona Geological Survey Map 35, 1 sheet, scale 1:1,000,000)

a) **Attention!** Please contact Surveying4Water.Com to convert the m station target identified on the charts (p-section) with the proper flagged drilling location.

b) The white lines (if any) which are shown on Fig. 2 are possible supplemental traverses that can be performed in other parts of the property. These additional traverses may help to better identify or confirm targets and their geometries and to allow a greater level-of-confidence in selecting the best target for follow-on drilling programs. If requested, Surveying4Water.Com can provide these proposed additional traverses.

c) These recon-level p-sections are shown on Fig. 3 (P34N), Fig. 4 (P33N), Fig. 5 (P32N), Fig. 6 (P02N), and Fig. 7 (P03NE). The locations of these traverses are shown on Fig. 2.

d) The summary of targets from these p-sections are listed below and in order of preferred drilling (1 - strongest target to 4 - weakest target):
   1. Profile P34N (Fig. 3) at Station 75 m;
   2. Profile.P32N (Fig. 5) at Station 50 m;
   3. Profile P33N (Fig. 4) at Station 75 m; and
   4. Profile P02N (Fig. 6) at Station 5 m.

   Profile P03NE shows no discernable target. The targets for P34N, P33N, and P32N are probably geologically related to each other. Please refer to paragraphs 2 of Sections 1 and 6; paragraph 7 of Section 3; and Section 7 for additional information on the hydrogeology of the area.

e) Please note that the above suggested location for additional investigations (including drilling) have been provided from interpretations of the data and the recon-level (minimum amounts) data collected for this property.

f) Should the client wish to proceed and install a test well from the results that have been developed from these charts and the hydrogeology; the selection of a target is at his/her own discretion.

g) In addition, Surveying4Water.Com recommends that between you and your drilling contractor, any follow-on investigations and drilling activity on this property be closely monitored and inspected during the drilling at the location(s) selected in this Commentary. Specific onsite monitoring should include the drilling phase (to ensure that the boring is within the recommended limits of being plumb and aligned and the geology is interpreted properly), well design (including selection of a filter/stabilizing pack, casing, well screen, sanitary seals, etc.), well construction, well development (especially in mud/air rotary drilled wells), and water quality and pumping tests of the well.

7. DEPTH OF DRILLING

The depth of drilling below the existing ground surface could vary between 200 and 500 ft for this property. The property is at an elev. of ≈ 2,720 ft amsl; the floor the Sacramento Valley Wash ranges between ≈ 1,720 to 1,800 ft amsl; and Colorado River elev. is ≈ 470 ft amsl. Drilling should not significantly exceed about 600 ft. However, deeper drilling may be recommended by the drilling contractor once he ascertains the shallow subsurface geologic, structural, and hydrogeologic conditions at the selected drilling location. Statistically, most computer-generated targets encounter water between 200 and 500 ft and may extend to 600 ft; if the client exceeds these depths then the client will be accepting the drillers' recommendations to drill deeper.

8. LIMITATIONS

Our services were performed using the degree of care and skill ordinarily exercised under similar circumstances by reputable engineers, geologists, hydrogeologists, or technicians practicing at the time that this Commentary was prepared. No other warranty, expressed or implied, is made as to the conclusions and professional advice presented in this Commentary.

Textures, structures, and geology of subsurface rocks (including type, strength, structure, grain-size, texture, etc.) can vary widely between the observation stations. Occurrences of GW in subsurface consolidated rocks can also vary widely due to textures (such as, but not limited to, clay layers in fracture zones and GW quality) or the works of man on this or adjacent properties. Small clay in-fillings (fault gouge) or clay layers are common with fractured rock and other geologic formations. The presence of these clays (low R especially if saturated) is difficult to identify using this method of exploration. In addition, clays (relatively low permeability but usually saturated with GW) can be a barrier to or reduce GW flow.

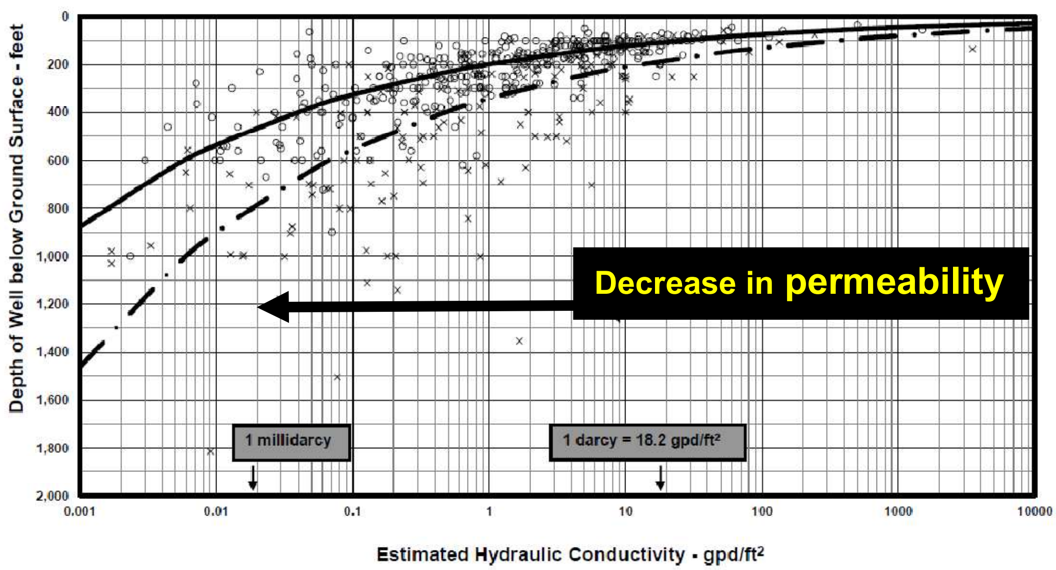
No deep subsurface exploration (i.e., borings, test holes, etc.) was authorized for this investigation. As a result, Surveying4Water.Com does not, and cannot, have complete knowledge of the subsurface rocks and their water-bearing characteristics or capacities beneath this property. The conclusions and recommendations within this Commentary are based on the findings at the observation stations and profiles as described herein and available geological information. In addition, no practical study would completely eliminate the uncertainty and risk with regard to subsurface characteristics in connection with this property.

It has been our experience that well yields are a function of several geologic and hydrologic properties as well as drilling methods and drilling systems rather than the actual depth of the well itself. These properties include the following: (1) the frequency of open fractures and aperture size (usually decrease with depth); (2) their hydraulic connection to the ground surface or an overlying aquifer; (3) the permeability of the fractures which decrease with depth (see Figure A – this page); (4) the extent and development of joint sets; (5) the length and placement of well screen intervals and filter/stabilizing pack; (6) the type of drilling method and well development techniques; and (7) the local climatic conditions. This is often the case in crystalline bedrock and arid environments.

Fracture patterns, permeable materials, or joint sets can be dramatically different from one area to another, and can change within a relatively short distance. Thus, a high-yield production well could be a short distance from a low-yield production well. Without proper and systematic pumping tests, it is difficult to predict the long-term capacity, reliability, and sustainability of the water supply well that taps a fracture rock resource.

Figure A: Rock Permeability" Distribution with Depth
(N_0 = 334 and N_1 = 146)

Data sets from Lee Valley, San Diego Co. and the western flanks of the Sierra Mountains, CA



Source: Abbott, D.W., 2007, Wells and Words column: Fractured rock aquifers – positive correlation between well depth and estimated hydraulic conductivity, in HydroVisions a quarterly publication of the Groundwater Resources Association of CA, Volume 16, No. 4, pages 4/5.

9. <u>THIS COMMENTARY IS NOT A SUBSTITUTE FOR LICENSED PROFESSIONAL</u>

This evaluation is <u>not intended</u> to be adequate for acquiring water well drilling permits, geotechnical engineering, and/or engineering geologic purposes, or an environmental assessment. If other subsurface structures are planned for the property, please contact the undersigned so the appropriate testing, analysis, and design can be performed.

State (ADWR) and local setback distances standards for fractured rock aquifers may be increased from unconsolidated sediment standards due to special hydrogeologic circumstances. The drilling contractor will confirm and verify the location setbacks for the water well with requirements from the local permitting and regulatory agencies; these agencies may have stricter standards. Some of the other criteria (logistical criteria) for siting a well include the following:

1. Accessibility for a drilling rig and service trucks;
2. Access to power to run the permanent pump;
3. Proximity to a water source (surface water, another well, or water main) for drilling fluids and any hydrogeologic criteria;
4. Proximity to final point of use of the water from the well;
5. Avoiding overhead power lines and underground utilities; and
6. The drilling rig footprint requires about a 50 ft by 100 ft working area.

The permitting agency is typically the state/county Health Department (in AZ it is the Department of Water Resources) which governs water well drilling permits and well development. The state/county hydrogeologist may collect a sample of water from the well for chemical analysis at a State Certified Laboratory. Based on results of this analytical test, the state/county hydrogeologist will determine if the water is potable and usable for human consumption.

Surveying4Water.Com appreciates the opportunity to offer services and advice on this project. In the event that you have any questions, please contact Surveying4Water.Com at your convenience. Surveying4Water.Com suggests that you make a copy of this emailed Commentary for your review, reference, and file; please attach this Commentary to the deed of the property.

10. <u>REFERENCES</u>

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11. LIST OF ACRONYMS AND ABBREVIATIONS

The table below is a list of acronyms and abbreviations used in this Commentary. The list is presented in alphabetical order.

≈ (approximately or about)	GW (groundwater)
ADWR (Arizona Department of Water Resources)	m (meters)
AMF (alternating magnetic field)	mi (mile)
amsl (above mean sea level)	PG (Professional Geologist)
AZ (Arizona)	p-section (pseudosection)
CA (California)	R (resistivity)
CHg (Certified Hydrogeologist)	Recon-level (reconnaissance-level)
EC (electrical conductivity)	topo (topographic)
elev. (elevation)	US (United States)
EM (electromagnetic)	USGS (US Geological Survey)
Fig. (figure)	VES (vertical electric sounding)
ft (feet)	VLF (very low frequency)
gpm (gallons per minute)	WCR (Well Completion Report)
G/S River (Gila and Salt River Base and Meridian)	

Sincerely,

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David W. Abbott, PG 4310, CHg 36

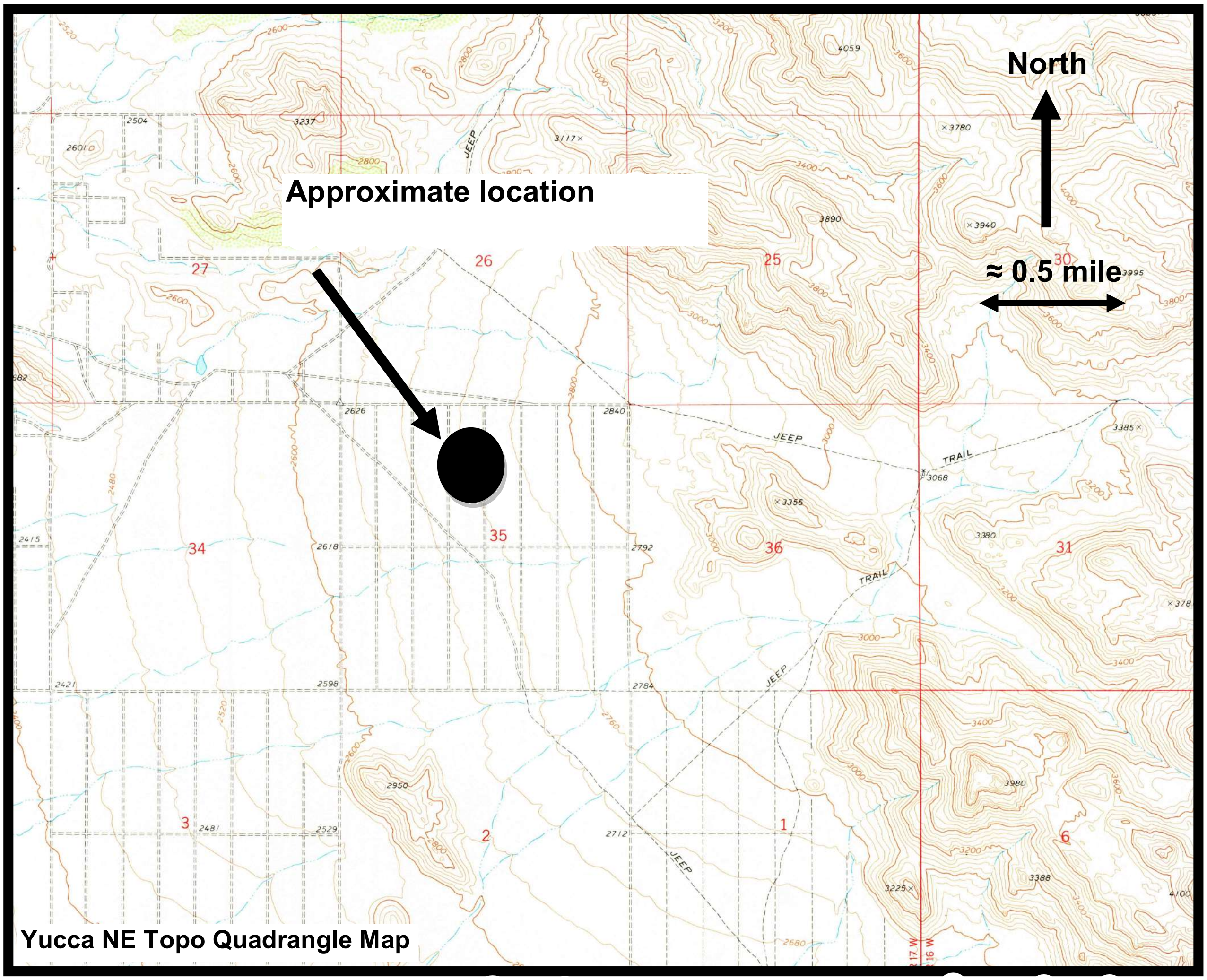


Figure 1 – Location Map of the property Topo Quadrangle Map (1970 edition) in Section River Base and Meridian.

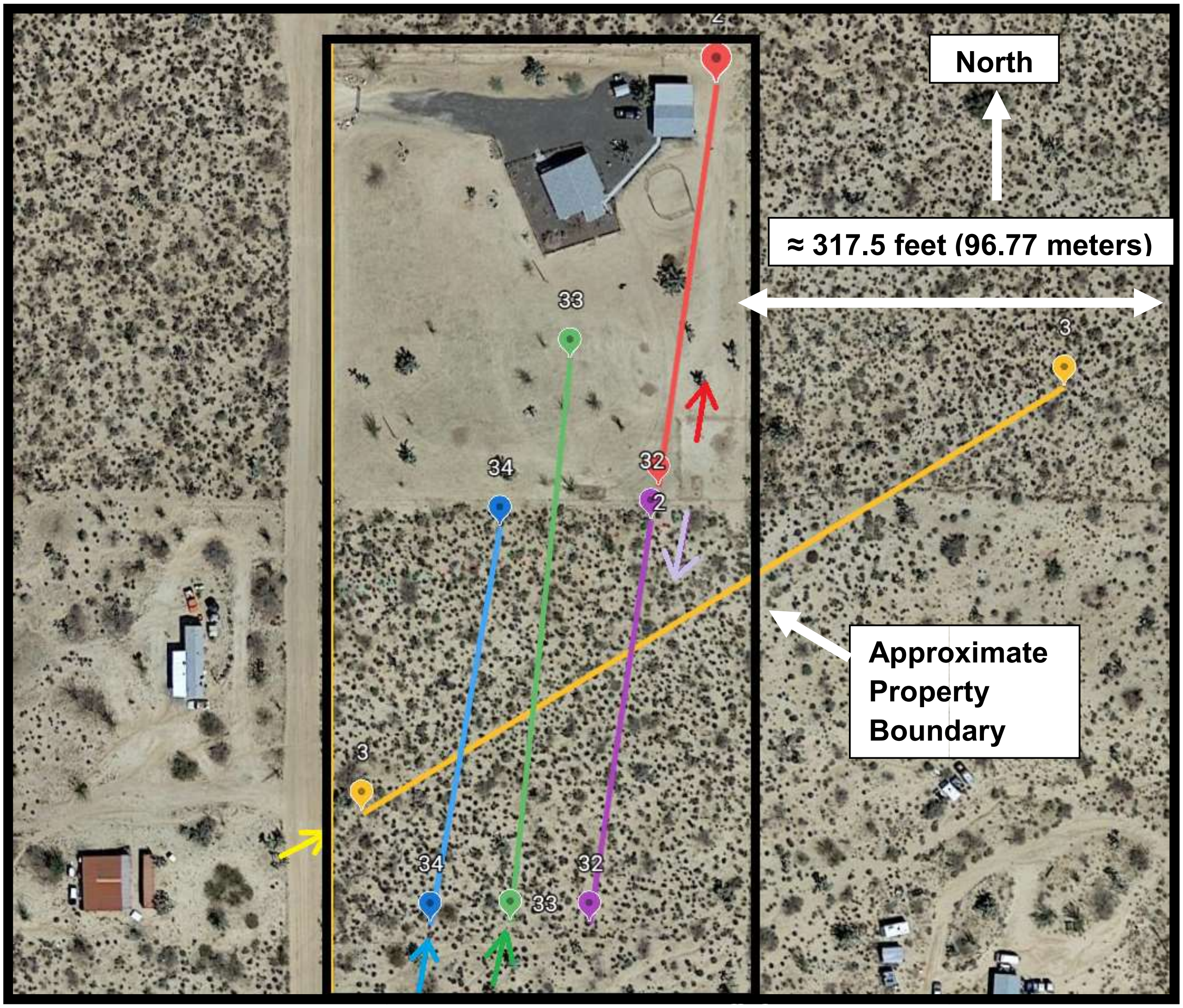


Figure 2 – Google Earth and Profile Plot Map of the property,

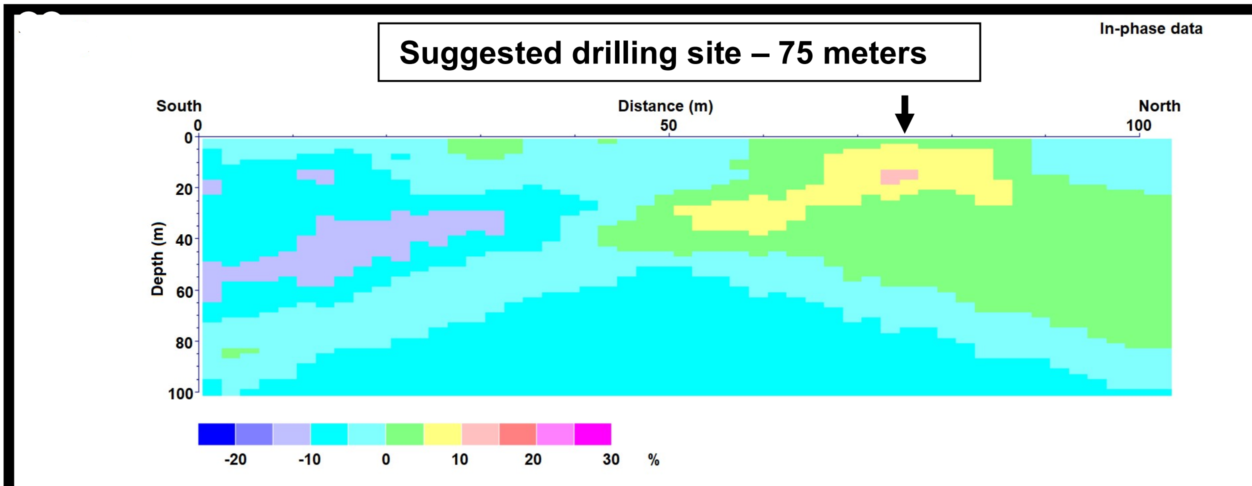


Figure 3 – Pseudosection for P0034N

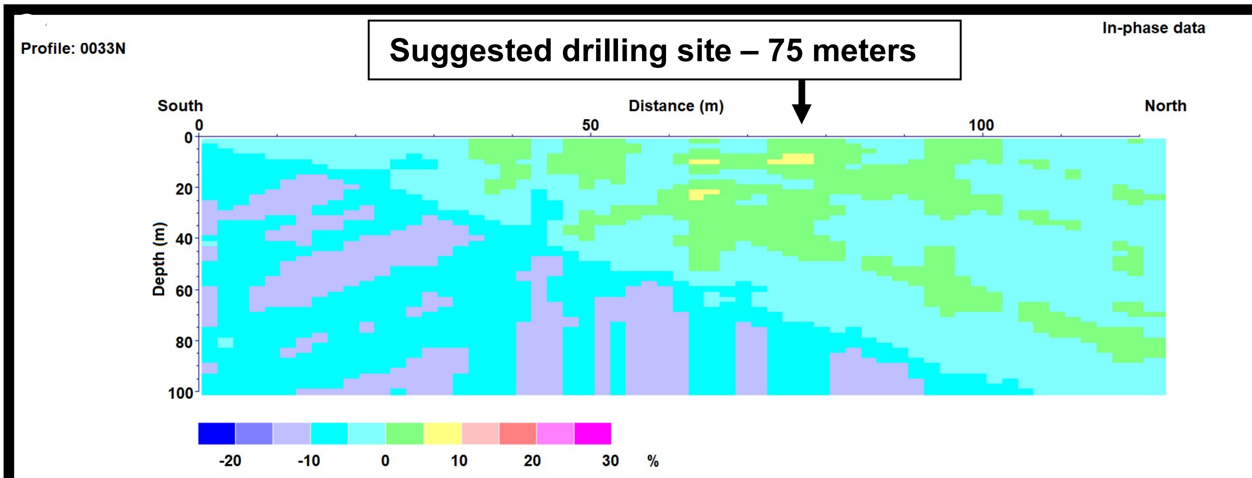


Figure 4 – Pseudosection for P0033N for the property,

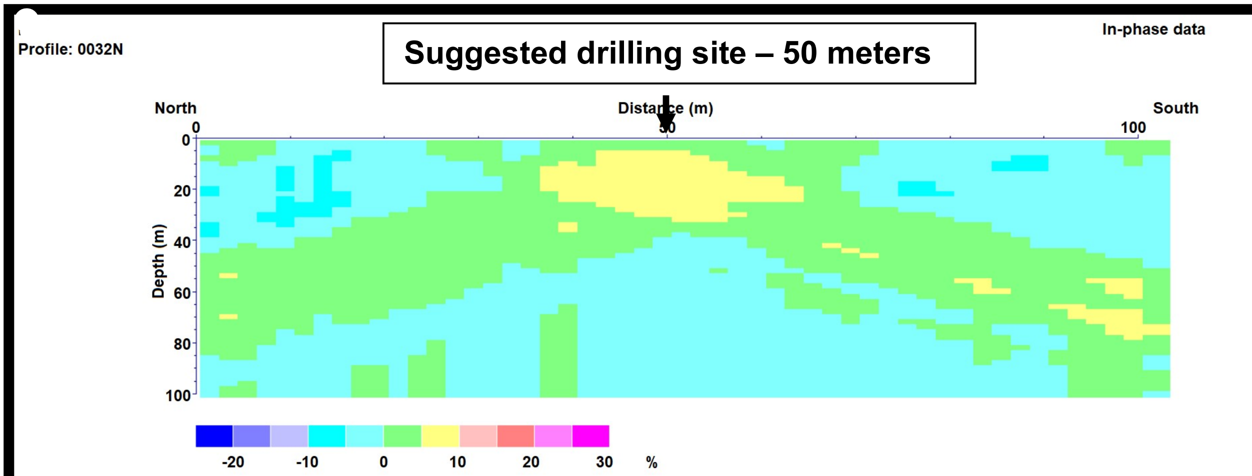
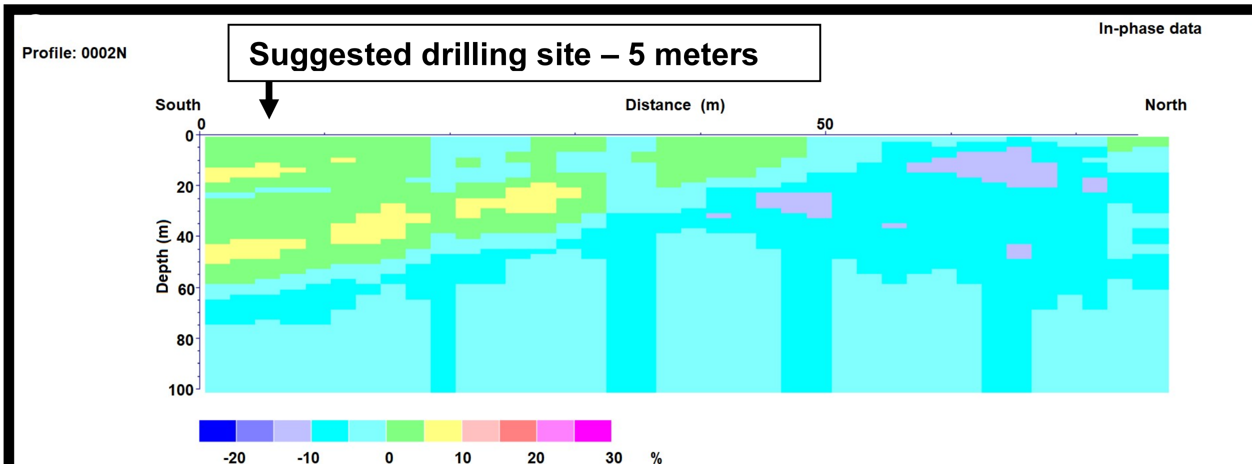


Figure 5 – Pseudosection for P0032N for the property,



Fiaure 6 – Pseudosection for P0002N for the property,

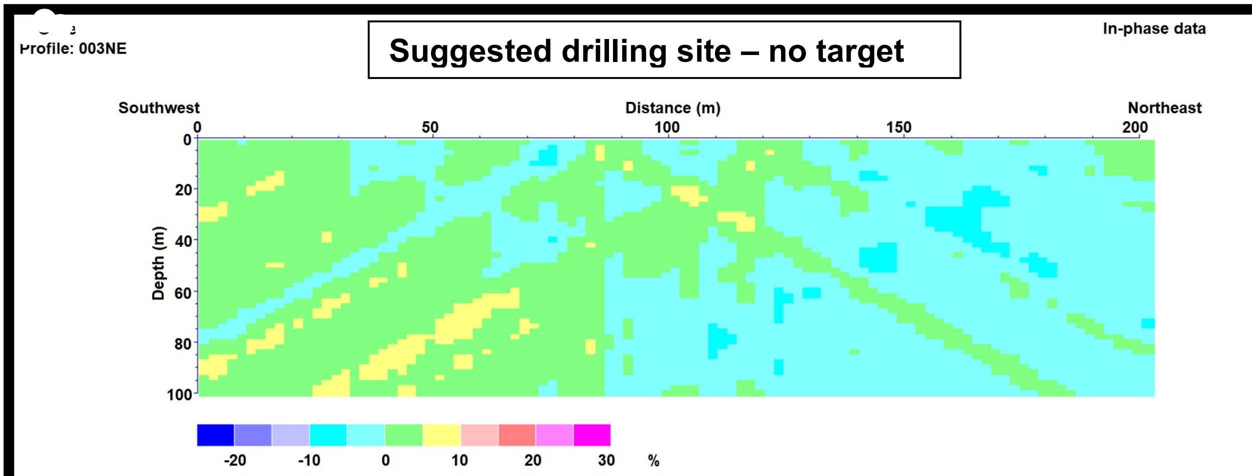


Figure 7 – Pseudosection for P0003NE for the property,