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HYDROGEOLOGY EVALUATION AND RESISTIVITY SURVEY SUMMARY REPORT

Malaga Cove Plaza Area, Palos Verdes Estates

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ACRONYMS AND ABBREVIATIONS

DC	Direct Current
DEM	Digital Elevation Model
ESE	East Southeast
Geosyntec	Geosyntec Consultants, Inc.
MSL	Mean Sea Level
USGS	United States Geological Society
WNW	West Northwest

EXECUTIVE SUMMARY

Background

Groundwater seepage around the Malaga Cove Plaza in Palos Verdes Estates, California, has been a persistent issue, particularly since 1983. The seepage has resulted in water infiltrating building foundations, necessitating the implementation of various dewatering and mitigation measures. However, these measures have proven costly and prone to operational failures.

Objective

The primary objective of this report is to identify the groundwater seepage pathways and depths to develop general engineering recommendations that can help reduce potential water seepage in the Malaga Cove Plaza area.

Methodology

The study employed a multi-faceted approach, including:

1. Reviewing historical reports and publicly available data such as aerial imagery, land use, and geological data.
2. Conducting a hydrogeology evaluation, which involved data compilation, historical imagery analysis, hydrology and watershed analysis, geological assessments, and infrastructure review.
3. Performing a geophysical resistivity survey to gather additional characterization data of the groundwater conditions.

Findings

Hydrogeology Evaluation

The study identified historical groundwater seepage locations and constructed a preliminary conceptual hydrogeology model. Key data gaps were noted, particularly in understanding the extent of preferential pathways and groundwater elevations.

Geophysical Resistivity Survey

Conducted along Via Campesina and Via Chico, the survey identified variations in subsurface resistivity, indicative of different geological formations and potential groundwater pathways.

Discussion and Recommendations

The conceptual hydrogeology model was revised based on the data collected by Geosyntec. Engineering mitigation options were proposed, including specific interventions for Via Campesina and Malaga Lane. Preliminary engineering designs were developed, and further research into utility partnerships and funding opportunities was recommended. Additional data collection, particularly groundwater seep samples, was suggested to refine the understanding of groundwater source(s).

1. INTRODUCTION

Geosyntec Consultants, Inc. (Geosyntec) presents this letter report summarizing a hydrogeological evaluation that identifies data gaps and characterizes groundwater conditions using geophysical techniques near Malaga Cove Plaza in Palos Verdes Estates, California (Figure 1).

The work described in this letter report was performed in accordance with proposals submitted to the City of Palos Verdes Estates representatives: "Hydrogeology Evaluation Services" dated November 21, 2023, and "Phase I Resistivity Survey for Hydrogeology Evaluations" dated February 22, 2024.

1.1 Background

Groundwater seepage in the Malaga Cove area has been observed by residents and businesses for many years. In the spring of 1993, water was reported seeping through the foundations and rear walls of the Malaga Cove Plaza in Palos Verdes Estates, California (Figure 1). This prompted the city to develop and implement dewatering mitigation measures to capture the seeping groundwater.

The mitigation measures included the use of dewatering wells and sump pumps to lower the water table. While these measures helped mitigate immediate water flow issues at the time, they have not been cost-effective due to the high expenses of pump operation and maintenance. To address these issues, the installation of a subdrain in the alley along Malaga Lane was proposed and completed in late 1997 (City of Palos Verdes Estates, Malaga Lane Subdrain Project, 1998). The subdrain initially helped reduce water intrusion issues for a period. However, its effectiveness has substantially declined over time and is no longer effective in limiting or reducing water intrusion issues (City of Palos Verdes Estates, Malaga Lane Subdrain Inspection, 2008). Groundwater seepage affecting the buildings in the Malaga Cove Plaza area has persisted, with year-round seepage increasing during years of excessive rainfall.

1.2 Objective

The objective of this report is to identify the groundwater seepage pathways, including their depths, to develop preliminary engineering recommendations that minimize seepage and prevent damage to the buildings in the Malaga Cove Plaza area.

To achieve this objective, Geosyntec performed the following:

- Reviewed and evaluated historical reports documenting groundwater seepage in the Malaga Cove area.
- Evaluated publicly available data sources, including historical aerial imagery, land use, surficial geology, structural geology, and hydrology data.
- Developed a preliminary conceptual hydrogeology model and identified known data gaps based on historical documentation and publicly available data review.
- Collected additional data to fill the identified known data gaps to refine the conceptual hydrogeology model.

- Identified groundwater pathways, including depths and the extent of preferential pathways (e.g., sand units), to develop preliminary engineering recommendations to manage groundwater seepage and reduce water intrusion related issues in the Malaga Cove Plaza area.

1.3 Report Organization

This report is organized into the following sections:

- **Section 1 – Introduction**: Includes the letter report introduction, , general background, and project objective.
- **Section 2 – Hydrogeology Evaluation**: Summarizes the review of historical and publicly available data, hydrology and watershed analysis, preliminary conceptual hydrogeology model, and identified known data gaps.
- **Section 3 – Geophysical Resistivity Survey**: Details the methodology and field activities for additional data collection using geophysical resistivity methods to fill data gaps and understand groundwater pathways.
- **Section 4 – Discussion and Recommendations**: Provides an updated conceptual hydrogeology model narrative using newly acquired geophysical data and discusses preliminary engineering solutions.
- **Section 5 – References**: Lists the references used in this report.

2. HYDROGEOLOGY EVALUATION

This section summarizes the review of historical reports and publicly available data, as well as hydrology and watershed analysis, performed by Geosyntec to develop a preliminary conceptual hydrogeology model. It also identifies known data gaps to better understand the groundwater seepage pathways affecting the Malaga Cove area.

2.1 Preliminary Data Review, Compilation, and Organization of Existing Data

Geosyntec reviewed existing relevant reports, publications, and data to organize hydrogeologic information for integration into a conceptual model of hydrogeology and groundwater flow in the Malaga Cove Plaza area. This also included infrastructure, geology, and groundwater data for the City of Palos Verdes Estates and Palos Verdes Peninsula area, as understanding the regional factors are essential for identifying additional potential factors that may affect the Malaga Cove Plaza area.

The historical reports, data, and geologic survey publications provided by the City of Palos Verdes Estate and gathered by Geosyntec have been collected over many years. Organizing this data is crucial to determine its validity and consistency. This process forms the foundation of the conceptual hydrogeology model, helps identify data gaps, and reduce potential redundancy in further data collection recommendations. Below is a list of the reports, publications, and data used in our review and evaluation.

- United States Geologic Survey Publications
- California Geologic Survey Publications
- Geology reports specific to the Palos Verdes Peninsula (Conrad and Ehlig, 1987)
- Precipitation data from Palos Verdes rain gauge stations
- Hydrologic surface discharge reports for nearby creeks
- Engineering Consulting and Construction Reports
    - Charles Abbot Associates, Inc. 1993
- City of Palos Verdes Estates, City Geologist Memorandum (1999)
- City of Palos Verdes Estates, Various reports associated with Malaga Cove Plaza groundwater and subdrain installation.
- Groundwater level and water quality data collected (City of Palos Verdes Estates)
- Boring and well construction logs (Psomas, 2011)
- Paul Chang, Master of Science Thesis, 2001
- GIS data including well & boring locations, storm drain system, imagery, geology, digital elevation model, parcels,

2.2 Historical Aerial Imagery

Historical orthogonal aerial photographs were acquired from the University of California Santa Barbara Aerial Imagery ("FrameFinder") Library. The FrameFinder tool allows users to search and download historical aerial photos with associated metadata dating back to approximately the 1920s. Key photos for the Malaga Cove area were identified from 1928, 1940, 1959, and 1979 (Figure 2). These photos show the land development in the Malaga Cove area, showing the city's growth to the south (higher ground elevation) and to the west. Publicly available topographic maps and United States Geological Services (USGS) digital elevation model (DEM) were also reviewed to evaluate the relationship between elevations, pre-development surface water drainages features, and the historical aerial photos.

The dominant topographic feature near Malaga Cove is a steep slope trending from south to north, descending from over 800 feet above mean sea level (MSL) to approximately 200 feet MSL at Malaga Cove Plaza (Figure 3). Based on topographic elevations and historical aerial imagery, surface water runoff appears to be concentrated along drainage courses flowing in a northerly to northwesterly direction, from higher to lower elevations, towards Malaga Cove. Groundwater flow, although slower and beneath the surface, may follow these same drainage courses.

In a 1928 aerial image (Figure 3), four drainage features are identified: three (labeled “2,” “3,” and “4”) that drain into the Malaga Cove Plaza area, and one (labeled “5”) located in the east. Commercial and residential development is concentrated in flatter areas, which are the endpoints of the surface drainage features, potentially indicating subsurface groundwater flow as well.

In a 1940 aerial image (Figure 4), the same four drainages course from 1928 are identified, along with an additional drainage course to the west (labeled “1”). The 1940 photo also shows a light-colored, northwest-trending linear feature extending from the end of drainage 3 across the site of the present-day Plaza. This feature may be the northern extension of drainage 3, supported by the location of current groundwater seeps.

2.3 Hydrology and Watershed Analysis

A watershed analysis was performed in ArcGIS Pro to assess the current configuration and location of drainages near Malaga Cove Plaza. Using a USGS DEM as input, the watershed boundary, including streams and drainages, was calculated using the Watershed Analysis geoprocessing tool in ArcGIS Pro (Figure 5). This process involved classifying flow direction and accumulation derived from the USGS DEM to determine the watershed boundary and the surface features responsible for the majority of surface water flow. Malaga Creek, north of Palos Verdes Estates City Hall, was used as the drainage endpoint.

The resulting watershed boundary and primary surface drainages are shown in Figure 5. The surface drainage features (1 through 5) interpreted from historical aerial imagery (Figures 3 and 4) closely correlate with the primary drainage features identified in this watershed analysis, except that the northern extension of drainage 3 trends north rather than northwest. The proximity of the seeps to the drainage suggests a hydrologic relationship.

2.4 Groundwater Level Data

Monitoring and dewatering wells associated with historical groundwater monitoring and seepage mitigation are shown in Figure 6. Water level measurements for these wells have not been consistently collected, resulting in sparse historical data. Well VC-1, located on Via Campesina, has the most available historical data, with measurements from October 2008 to October 2013 (Figure 7).

The most recent groundwater level measurements were collected on January 9, 2024 by Geosyntec staff. These measurements are listed in Table 1 below.

Table 1: Groundwater Level Measurements

Well Name	Depth-to-Water (feet bgs)	Total Depth (feet bgs)
PVE-1	Dry	34.0
PVE-2	Dry	13.2
PVE-3	Dry	38.7
PVE-4	6.98	13.2
PVE-5	Dry	28.75
PVE-6	Dry	27.7
VC-1	11.3	28.1
A-4	9.28	17.5
A-1	7.5	17.2

Notes:
bgs – below ground surface (approximate)
dry – well does not contain a measurable amount of water
Depth-to-Water – depth to water measured from the ground surface
Total Depth – depth to the bottom of the well

Figure 7 displays historical groundwater levels for well VC-1 alongside the groundwater level measurement recorded on January 9, 2024. This time-series graph also includes monthly precipitation data from 2008 to 2024 and the approximate depth of a previously identified sand unit (Chang, 2001). The graph indicates that the January 2024 water levels are close to the highest values recorded for well VC-1 from 2008 to 2013.

Overall, shallow groundwater is primarily located between Via Campesina and Via Tejon, and northeast of Via Corta. This interpretation is based on the comparison of dry wells with the locations of wells containing water (PVE-4, VC-1, A-4, and A-1), as shown in Table 1.

2.5 Geology

The Palos Verdes Peninsula including City of Palos Verdes Estates has a diverse and complex geology characterized by its unique uplifted and folded sedimentary rock formations. The geological history of the area includes, formation and uplift, tectonic activity, erosional features, and deposits that are vastly different from the Los Angeles Basin a short distance to the north across the multiple fault zones. This unique geological setting results in several geohazards, including slope stability issues, groundwater seepage, and fractured flow paths. The sections below provide a summary of the surficial geologic deposits and a brief discussion on the broader geological structural setting encompassing the City.

2.5.1 Surficial Deposits

Geologic maps (Cleveland, 1976 and Dibblee, 1999) and literature were reviewed to understand the relationship between geologic units and known locations of seepage and shallow groundwater. The surficial geologic units near Malaga Cove area include terrace deposits, alluvial deposits, slump, creep, and slope wash deposits, as well as lagoon, beach, and dune sands (Figure 8). Slump, creep, and slope wash deposits are prevalent in the south where the topography is steep, while lagoon, beach, and dune sands are common in the flatter northern areas, with scattered terrace and alluvial deposits along stream channels. Notably, most known seepage locations and monitoring wells with shallow groundwater are within the lagoon, beach, and dune sands surficial geological units.

2.5.2 Boring Logs

Boring logs for locations B-1 and PVE-1 through PVE-6 (Figure 6) were reviewed to develop a general understanding of the site-specific geology encountered during drilling activities. A summary of the geologic conditions is provided in Table 2 below.

Table 2: Summary of Boring Log Geology

Boring/Well Name	Boring Log Summary (feet bgs)
B-1	0-14 (Clay)
PVE-1	0-15 (Clay), 15-30 (Poorly Graded Sand), 30-36 (Clay)
PVE-2	0-5 (Clay), 5-14 (Poorly Graded Sand), 14-16 (Clay)
PVE-3	0-35 (Clay)
PVE-4	0-12 (Clay), 12-22 (Poorly Graded Sand), 22-30 (Clay)
PVE-5	0-15 (Clay), 15-22 (Poorly Graded Sand), 22-29 (Clay)
PVE-6	0-14 (Clay), 14-26 (Poorly Graded Sand), 26-28 (Clay)

All depths are feet below ground surface (approximate)

2.5.3 Regional Geology

The Palos Verdes Peninsula, including Palos Verdes Estates and the Malaga Cove area, is influenced by several significant fault systems, which contribute to its complex geology and geohazards (Figure 9). Key faults in or near the peninsula include:

- Palos Verdes Fault System: This major fault system trends northwest-southeast and runs along the eastern edge of the peninsula, playing a crucial role in the region's tectonic activity and uplift.

- Cabrillo Fault System: Located to the southwest of the peninsula, this fault system also trends northwest-southeast, contributing to the area's structural complexity and landform stability.

- Other Faults: Several smaller faults generally follow a northwest-southeast directional trend, adding to the region's geological diversity and geohazards, such as slope instability and groundwater seepage.

Overall, the northwest-southeast trending faults, including the Palos Verdes and Cabrillo fault systems, significantly shape the geological and structural characteristics of the Palos Verdes Peninsula.

2.6 Drain Infrastructure

The existing drainage infrastructure around Malaga Cove Plaza was reviewed using available public data and GIS data provided by the City (Figure 10). Storm drains run parallel to Via Corta and Via Chico, following the down-gradient elevation paths of Drainages 2 and 3, as previously discussed in Section 2.2, and cross Via Campesina.

Notable subsurface infrastructure was identified along Via Chico, south of Via Campesina (e.g., Chico Path), as shown in Figure 11 during site walk activities. City staff have noted that many of the existing utility vaults along Via Chico contain standing water.

2.7 Public Water Source

Cal Water Service (Cal Water) has been providing water to the Palos Verdes Peninsula since 1970. The water is sourced from the California State Water Project and/or the Colorado River via the Metropolitan Water District. During this evaluation, no evidence of compromised water supply infrastructure was found during site walks performed by Geosyntec.

2.8 Known Groundwater Seepage Locations

Groundwater seepage locations are visually noticeable throughout the Malaga Cove Plaza area, with flowing water observed during site walks. However, some seepage points are not visible from street level. City of Palos Verdes Estates staff have communicated with concerned residents and property owners in the Malaga Cove Plaza area to document the known groundwater seepage locations, as shown in Figure 12.

2.9 Preliminary Conceptual Hydrogeology Model

Building on the conceptual hydrogeology model developed by Chang (2001) (Figure 13) and incorporating information and evaluations from Sections 2.2 to 2.8, a conceptual hydrogeology model of the groundwater flow paths and preferential pathways potentially affecting Malaga Cove Plaza buildings is described below.

Precipitation falls on the permeable surface soils in the higher elevations of the watershed and flows north towards Malaga Creek and Malaga Cove Plaza. Precipitation water travels along surface drainage pathways, accumulating in natural basins along these paths. The precipitation water then infiltrates into the water-bearing geologic units or dune sands, possibly combining with other water sources from land use (e.g., landscaping) before becoming groundwater. Groundwater continues to flow north, preferentially migrating through permeable sand units before emerging as seeps in the Malaga Cove Plaza buildings. Some areas along or south of Via Campesina do not exhibit groundwater seepage because these properties may be underlain by adobe soil acting as a confining layer over the permeable sand units.

Key observations from this evaluation include:

- Natural surface drainage 2 follows the same path as Via Corta and the parallel storm drains (Figures 3 and 10).
- Natural surface drainage 3 follows the same path as Via Chico/Chico Path and the parallel storm drains (Figures 4 and 10).
- Major seeps along Via Chico may be related to natural surface drainage 3 (Figure 3, 4, and 12).
- Seepage occurs mostly in areas mapped as lagoon, beach, or dune sands (Figure 8).
- Groundwater seepage in Malaga Cove Plaza buildings begins just north of Via Campesina in the sandy surficial units (Figure 8 and 12).

These observations provide a preliminary understanding of groundwater flow in the Malaga Cove Plaza area based on available data. This conceptual understanding, derived from a variety of data types and sources compiled over time, indicates that additional data was needed to develop an engineering solution to mitigate groundwater seepage affecting the Malaga Cove Plaza buildings.

2.10 Data Gaps

Based on the review of available relevant document and the conceptual hydrogeologic model described in the previous sections of this letter report, some data gaps necessary to effectively characterize the hydrogeological conditions causing groundwater seepage in the Malaga Cove Plaza area were identified. The primary data gaps impacting potential engineering mitigation solutions are discussed below and summarized in Table 3.

2.10.1 Extent of Preferential Pathways

The extent and depth of preferential pathways, such as dune sand units, are not well known. Limited information is available from the boring logs discussed in Section 2.5.2, and the well borings were not specifically aimed at characterizing these sand units. Therefore, additional data collection was necessary to delineate the preferential pathways.

There are various methods to collect additional shallow geologic data, including drilling boreholes. However, the number of borings required to characterize the area along Via Chico and Via Campesina would be extensive, and the presence of subsurface utilities complicates drilling activities. There is a significant risk of penetrating utilities in areas with complex and overlapping infrastructure, such as at the intersection of Via Chico and Via Campesina. Additionally, boring data would be limited in extent, resulting in restricted interpretations.

To address these challenges, Geosyntec proposes conducting a surface geophysical resistivity survey to characterize the complex geology along Via Chico/Chico Path and Via Campesina. This survey applies Ohm’s law to measure the resistivity of the underlying soil, which is then interpreted to identify preferential pathways. The data is collected at a much higher density, allowing for a more detailed interpretation of the extent of these pathways. This method is preferred due to the high likelihood of complex geology in the area.

2.10.2 Groundwater Source

The exact source(s) of groundwater seeping into the Malaga Cove Plaza buildings year-round, including in summer, is currently unknown. To better understand the source(s), groundwater seepage chemistry should be collected following the evaluation of preferential pathways discussed in Section 2.10.1.

To characterize the groundwater source, samples of the seepage water should be collected from as many seepage points as possible and analyzed for general chemistry. This includes testing for cations and anions, total dissolved solids, pH, conductivity, metals, etc. The results should then be plotted and compared to the chemical signatures of known water sources, such as California State Water Project water and seawater. This evaluation can be relatively inexpensive, covering the costs of sampling, lab analysis, and data analysis.

2.10.3 Develop Water Balance

After resolving the data gaps discussed in Sections 2.10.1 and 2.10.2, an effort should be made to quantify the volume of water entering the Malaga Cove Plaza groundwater system. By using the dimensions of the preferential pathways, estimated flow rates, and identified groundwater sources, it is possible to estimate the volume of groundwater entering the system and the amount of water that needs to be captured to mitigate the seepage issues.

Table 3: Data Gap Summary

Data Gap	Data Gap Resolution
Extent of Preferential Pathways (e.g., sand units)	Surface resistivity geophysical survey
Groundwater Source	Collect water samples, perform general minerals analysis
Water Balance	Using results of the above-mentioned data gaps, develop the approximate volumetric rate of water entering the affected area of Malaga Cove Plaza and the amount leaving the systems for sump design purposes

3. GEOPHYSICAL RESITIVITY SURVEY

As discussed in Section 2.10.1, the extent and depth of preferential pathways, such as dune sand units, were not well known. Therefore, additional data collection was necessary to delineate these pathways. To address this, Geosyntec proposed conducting a surface geophysical resistivity survey to characterize the complex geology along Via Chico/Chico Path and Via Campesina near Malaga Cove Plaza (Figure 14).

Following discussions with the City regarding our Hydrogeology Evaluation (Section 2) and the limited data available to develop an engineering mitigation recommendations for groundwater seepage in the Malaga Cove Plaza buildings, Geosyntec prepared an approach in collaboration with a specialty geophysical subcontractor. This approach aimed to acquire high-resolution data to interpret the complex geology affecting the Malaga Cove Plaza buildings. The work includes electrical resistivity surveys as shown on Figure 14 and described below:

- A-A': An approximate 708-foot resistivity transect line from Via Corta southwest along Via Campesina to the curve of Via Campesina to the northeast. This line is intended to characterize the hydrogeology and groundwater perpendicular to the interpreted groundwater flow direction.
- B-B': An approximate 541-foot resistivity transect line from Via Pinale southeast along Chico Path and Via Chico towards the Malaga Cove Plaza bridge to the northwest. This line is intended to characterize the hydrogeology and groundwater parallel to the interpreted groundwater flow direction.

The following sections describe the methodology, field activities, and results of the surface geophysical resistivity survey.

3.1 Methodology

Spectrum Geophysics, a subcontractor based in Huntington Beach, was hired to perform electrical resistivity survey services using direct current (DC) electrical resistivity methods. For the 2-dimensional electrical resistivity survey, a DC circuit was established in the ground using cables and a linear array of electrodes. During data collection, a known amount of current is applied to the ground through a pair of current electrodes. The voltage is then measured between another pair of potential electrodes located 6-feet away from the current electrodes, with the ground acting as the resistor to complete the circuit. Ohm’s Law (Voltage = Current × Resistance) is used to calculate the electrical resistance of the ground through which the current has traveled (termed electrical resistivity). The measured electrical resistivity values are then used to interpret subsurface lithology and features of interest including variations in grain size and permeability, as well as potential structural features such as faults, folds, and fractures in the subsurface.

For this investigation, electrical resistivity data were collected with an AGI SuperSting R8/IP automated resistivity system (SuperSting) and associated resistivity cabling. Data were collected along Lines 1 and 2 using a linear array of 56 electrodes spaced 3 meters apart, utilizing both Schlumberger and dipole-dipole array geometries to obtain a 2D image of the subsurface materials along each line. The SuperSting system collects data in meters, which are subsequently converted to feet.

Further details on the methodology and implementation of the resistivity survey can be found in Appendix A – Spectrum Geophysics, Summary Report – Geophysical Investigation.

3.2 Field Implementation

The following sections describe the field implementation, including pre-field activities and on-site field activities.

3.2.1 Pre-Field Activities

Geosyntec staff coordinated with City Public Works staff to discuss the scope of work, traffic and lane closures, parking impact, and the duration of the field activities. Key meetings included:

- April 11, 2024: Met with City Public Works staff to walk the site and plan for traffic and lane closures, as well as parking closures, necessary for the field work.
- April 17, 2024: Notified Underground Services Alert that shallow hand drilling would be conducted to set electrodes in the native soil beneath the road asphalt and base.

3.2.2 Field Activities

Spectrum Geophysics, under Geosyntec's oversight, implemented the resistivity surveys in coordination with City Public Works staff to manage traffic, lane closures, and parking notifications. The work occurred on the following days:

- April 22, 2024: Prepared each transect for the resistivity survey, including locating subsurface utilities and pre-marking electrode locations.
- April 23, 2024: Conducted the resistivity survey A-A' along Via Campesina (Figure 14).
- April 24, 2024: Continued and completed the resistivity survey A-A' along Via Campesina (Figure 14).
- April 25, 2024: Conducted and completed the resistivity survey B-B' along Via Chico and Chico Path (Figure 14).
- April 26, 2024: Completed asphalt cold patching and surveyed the electrode locations.

Due to the presence of utilities along both A-A’ and B-B’ (especially along Chico Path on B-B’ and at the intersection of Via Chico and Via Campesina for both lines), utilities were located and marked near the transects. Care was taken to offset electrode locations from utilities and utility vaults as much as possible to minimize electromagnetic interference. These offsets were measured and used during data processing to adjust electrode geometry as necessary.

3.2.2.1 A-A’ (Via Campesina)

Transect A-A’ ran southwest-northeast along the northwest side of Via Campesina, covering a length of 708 feet. It began at Via Corta, extended across the intersection of Via Chico and Via Campesina, and continued to the point where Via Campesina starts to bend southeast.

3.2.2.2 B-B’ (Via Chico)

Transect B-B’ ran southeast-northwest, roughly parallel to Via Chico, and was 541 feet in length. To maximize depth detection, the line originated at Chico Path near Via Pinale, continued down

Chico Path, crossed the intersection of Via Chico and Via Campesina, and then ran along the southwest side of Via Chico, ending at the brick archway.

After the data were collected, the Spectrum crew surveyed the elevations of each station along each line, converting these to MSL elevations using a benchmark provided by Geosyntec. The data files were then downloaded to a laptop and saved for subsequent office processing. During office processing, a resistivity geophysical inversion routine was used for each profile to obtain 2D models of the electrical resistivity distribution beneath the ground surface along A-A’ and B-B’, reaching depths of approximately 60 feet where possible. Further details on the electrical resistivity methods are provided in Appendix A.

3.3 Resistivity Results

The electrical resistivity profiles for A-A’ and B-B’ are shown on Figures 15 and 16, respectively, with an interrupted fault block displayed on Figure 17. The colors in Figures 15 and 16 represent resistivity values using a “modified rainbow” color scheme, which is illustrated on the right side of these figures. The lowest resistivity values, indicating the most electrically conductive materials, are depicted in dark blue. As resistivity values increase, along with the grain size of subsurface materials, the colors transition from blues to greens, yellows, oranges, reds, and finally to dark red for the highest resistivity.

These resistivity values were interpreted by a Geosyntec CA-licensed hydrogeologist and a Spectrum Geophysics CA-licensed geophysicist. Their goal was to understand the site's lithology, geology, and hydrogeologic features, such as permeable versus impermeable geologic units, by correlating the resistivity data with available geologic maps and known hydrogeology in and around the Malaga Cove Plaza area. This interpretation allowed for the identification of specific geologic units (e.g., sand versus shale), geologic structures (e.g., dipping versus flat-lying layers), and geologic/hydrogeologic contacts (e.g., terrace deposits overlying shale, or dry soils underlain by saturated materials).

3.3.1 Resistivity Interpretation

Based on the review of publicly available geologic maps (Section 2.5), mapped geologic contacts through the Malaga Plaza area (Conrad and Ehlig, 1987), known depths to groundwater measured in January 2024 (Section 2.4), and field observations, the following site-specific interpretation of resistivity values for groundwater and geology was made for this study area:

- <u>Conductive groundwater</u>: Resistivity values from 0.1 to 3 Ohm-meters (darkest blue).
- <u>Fine-grained soils or clay</u>: Resistivity values from 3 to 7 Ohm-meters (blue to light blue) likely indicate soils with clay or fractured shale where continuous.
- <u>Silt to sand</u>: Resistivity values from 8 to 30 Ohm-meters (green to yellow) likely represent soils ranging from silt to sand, with resistivity increasing with the percentage of sand, coarse-grained material, or shale fragments.
- <u>Shale, dry sand, or terrace deposits</u>: Resistivity values ranging from 30 to 70 Ohm-meters (yellow to orange) may indicate dry cherty or calcareous Altamira Shale, dry sand, or moderate to coarse-grained alluvium or terrace deposits.

- Valmonte Diatomite: Areas with resistivity values showing a steep lateral or vertical gradient, increasing sharply from 60 (orange) to 300 (brown) to above 1000 (dark red) Ohm-meters, are interpreted as the Valmonte Diatomite unit of the Monterey Formation.

These resistivity interpretations are key to developing a conceptual model of groundwater flow in the Malaga Cove Plaza area. Based on these interpretations and correlations across the profiles, the following has been determined:

- A steeply south-dipping, nearly vertical reverse fault, or fault block, approximately 120 feet wide and oriented West-Northwest (WNW)-East Southeast (ESE), runs through the intersection of Via Chico and Via Campesina and extends to the WNW beneath a portion of Malaga Cove Plaza (Figures 16 and 17). This fault block may be associated with the Palos Verdes Fault Zone, Cabrillo Fault Zone, or Redondo Canyon Fault Zone.
- This fault block appears to offset the permeable Altamira Shale (south side) with the impermeable Valmonte Diatomite unit (north side), causing shallow groundwater to be trapped or perched within the fault block (Figure 16).
- The fault block is bordered on either side by a vertically or sub-vertically oriented fractured zone of conductive groundwater, which appears to be migrating vertically (Figures 16).
- Data collected along B-B' (Via Chico) suggest that conductive groundwater may be confined beneath the Valmonte Diatomite at depth around the fault block. This water, potentially under pressure, may be rising through the vertical or sub-vertical fractured zones (Figure 16).

Further discussion on profiles A-A' and B-B' is provided below.

3.3.1.1 A-A' (Via Campesina)

The resistivity profile for A-A' is shown on Figure 15. The horizontal axis represents ground distance (Station) in feet along the line, and the vertical axis represents MSL elevations in feet. The data collected along A-A' were noisier due to the presence of numerous metallic or conductive utilities, particularly steel or steel-reinforced storm drain lines, storm drain vaults, and steel water lines. These features caused noisy and erroneous data points at depth and at the northeast end of A-A'. Surface features, tie points, and key interpreted geologic and hydrogeologic units are labeled on the profile on Figure 15.

Fault Block

The southern-southwestern boundary of the fault block is indicated by a heavy dashed black line on Figure 15, approximately at Station 420 on A-A'. Northeast of Station 420, the contact with the Valmonte Diatomite unit is identified by a high resistivity anomaly (300 to 3,000 Ohm-meters) occurring at about 69 feet bgs (171 feet MSL). This contact rises roughly 20 feet in elevation beneath Via Chico around Station 480.

South of Station 420, a 40-foot wide vertical to subvertical zone of fractured, saturated rock is evident between Stations 380 and 420, characterized by very low resistivity values (0.1 to 3 Ohm-meters, darkest blue to deep blue). This zone, interpreted as bordering the main fault, suggests vertically rising conductive water through fractured rock. Southwest of this zone, a lower layer of Altamira Shale is likely present at about 68 feet bgs, indicated by moderate resistivity values (12 to 20 Ohm-meters, green to yellow).

The northeastern boundary of the fault block appears around Station 620 at a depth of about 65 feet bgs (178 feet MSL), where there is a drop in resistivity, suggesting another zone of water-saturated fractured rock. However, this feature is less well resolved due to data tapering off at depth.

Along the southern boundary of the fault block, the vertically migrating zone of conductive, water-filled fractured rock narrows southeastward, from about 30 feet wide on A-A’ to 12 feet wide at the south end of B-B’. This narrowing indicates a "pinch point" where the rising water is likely under greater pressure north of Station 248 on B-B’.

Groundwater

The depth to groundwater along A-A’ was interpreted using resistivity data, correlations with known groundwater depths in wells PVE-4 and VC-1, and field observations of water in vaults and catch basins. The approximate groundwater depth between VC-1 and the north end of the fault block is shown with a dashed pink line on Figure 15. In areas with extensive utility interference, such as between Stations 420 and 590, the groundwater contact is interpolated and smoothed between "clean" data points, indicated by low resistivity values (darkest blue to deep blue). Utility interference typically appears as higher resistivity values, such as those from a metallic storm drain vault and reinforced concrete storm drain between Stations 535 and 570, labeled on Figure 15.

The depth to perched groundwater ranges from 2.5 to about 12 feet bgs between Stations 370 and 590 and drops to between 22 and 28 feet bgs between Stations 600 and 620. The thickness of the saturated perched zone above the Valmonte ranges from about 38 to 66 feet beneath the fault block area. A grid is superimposed on the profile of A-A’ to clarify elevations of key features, and a summary of groundwater depths, elevations, and key contacts along A-A’ is provided in Table 4.

An area where deeper groundwater rises to the surface or near-surface levels (e.g., upwelling) of conductive groundwater southwest of the fault block is evident between Stations 250 and 300. This is shown by a 15-foot-thick layer of very low resistivity values (0.3 to 2 Ohm-meters, darkest blue) over a vertically oriented highly resistive feature (dark red) at about 35 feet bgs at Station 275. This low resistivity layer could correspond to conductive groundwater upwelling around a resistive/impermeable nodule, based on groundwater data from well VC-1. However, a metallic storm drain lateral may also be present, as labeled in Figure 15. The apparent perched groundwater contact is indicated with a dashed pink line, ranging from 10 feet (high point at Station 275) to 32 feet bgs between Stations 250 and 300.

Southwest of this feature, between Stations 0 and 240, the near-surface data show variable resistivity values typical of alluvium, likely associated with terrace deposits based on geologic maps for the Malaga Cove Plaza area.

3.3.1.2 B-B’ (Via Chico)

The resistivity profile for B-B’ is shown in Figure 16. The horizontal axis represents ground distance (Station) in feet, and the vertical axis represents MSL elevations in feet. The data along B-B’ provide an investigation depth of about 130 feet bgs for most of the profile, with data tapering at both ends due to limitations of the DC resistivity method. Key surface features and tie points, such as the Via Campesina right of way and the boundaries of Malaga Lane, along with key interpreted geologic and hydrogeologic units, are labeled on the profile in Figure 16.

Fault Block

The boundaries of the interpreted fault block on B-B’ are shown with a heavy dashed black line in Figure 16. The resistivity data indicate that the fault block offsets the Altamira Shale unit of the Monterey Formation (to the south at about 22 feet bgs) with the Valmonte Diatomite unit (to the north at about 32 feet bgs). Between these two units is a near-vertical, steeply south-dipping zone of fractured, saturated rock.

The south end of the fault block projects to Station 270 on B-B’, with the vertical/subvertical zone of fractured saturated rock evident between Stations 250 and 270, indicated by very low to low resistivity values (0.1 to 3 Ohm-meters, darkest blue to deep blue) extending from depth. This suggests the presence of conductive, high TDS water rising vertically through the fractured rock. South of this zone (south of Station 248), the Altamira Shale is interpreted based on a layer of moderate resistivity values, overlain by lower resistivity soils or alluvium, likely terrace deposits.

At Station 270, the Valmonte Diatomite unit appears at about 32 feet bgs, marked by very high resistivity values (500 to 3,000 Ohm-meters, brown to dark red) about 50 feet thick, extending to the north end of the fault block at Station 430. These high resistivity values suggest the Valmonte is impermeable, causing groundwater to perch above it. The top of the Valmonte contact varies between 26 and 48 feet bgs, generally around 35 to 37 feet deep within the fault block. The north end of the fault block projects to Station 430, bounded by another steeply south-dipping, fractured, and water-saturated zone, possibly with conductive water migrating sub-vertically (particularly between Stations 430 and 440). This zone lies beneath Malaga Lane.

Northwest of the fault block, the Valmonte appears to be absent, with the second reverse fault at Station 430 offsetting Valmonte to the south against saturated dune sand to the north. Beginning at Station 460, at about 40 feet deep, another high resistivity/likely impermeable contact is present, though not well resolved as data taper off at depth in this area.

Groundwater

The depth to groundwater along B-B’ was interpreted using resistivity data, known groundwater depths in the Malaga Cove Plaza area, and field observations of water in vaults and catch basins. The approximate groundwater depth beneath and northwest of the fault block is shown with a dashed pink line on Figure 16. This interpretation is based on a sharp drop in resistivity, assuming groundwater has a resistivity value between 0.1 and 3 Ohm-meters (darkest to deep blue colors). Although groundwater may undulate or exist in pockets, the contact is smoothed and generalized.

The depth to perched groundwater ranges from 2 to 13 feet bgs beneath the fault block and drops to 12 to 15 feet bgs northwest of Station 450. The saturated perched zone above the Valmonte ranges from 13 to 41 feet thick, generally about 25 to 35 feet beneath the fault block. A summary of groundwater depths, elevations, and key contacts along B-B’ is provided in Table 5.

Additionally, a layer of low to very low resistivity (0.7 to 3 Ohm-meters) is evident between 100 and 110 feet bgs (130 feet MSL) beneath the Valmonte between Stations 285 and 382. This suggests a possible zone of confined conductive groundwater, connected to the subvertical zones of conductive water on either side of the fault block.

Table 4: A-A' Groundwater Elevations and Feature Depths

Station (feet)	Surface Elevation (feet MSL)	Groundwater Elevation (feet MSL)	Bottom of Water/top of Impermeable unit (feet MSL)	Depth to Water (feet bgs)	Thickness of Water Zone (feet)	Depth to Impermeable Unit (feet bgs)	Comments
250	240.6	207.2	NA	33.4	Unknown	NA	Upwelling around SD lateral/resistive nodule?
260	240.6	217.3	NA	23.3	Unknown	NA	Upwelling around SD lateral/resistive nodule?
270	240.6	225.9	201.7	14.7	24.2	38.9	Upwelling around SD lateral/resistive nodule?
280	240.6	218.7	205.7	21.9	13	34.9	Upwelling around SD lateral/resistive nodule?
290	240.6	210.8	175.9	29.8	34.9	64.7	Upwelling around SD lateral/resistive nodule?
300	240.6	208.8	174.4	31.8	34.4	66.2	Upwelling around SD lateral/resistive nodule?
310	240.6	202.7	NA	37.9	Unknown	NA	--
320	240.6	195.1	NA	45.5	Unknown	NA	--
330	240.6	187	NA	53.6	Unknown	NA	--
340	240	186.5	NA	53.5	Unknown	NA	--
350	240	191.6	NA	48.4	Unknown	NA	--
360	240	196.1	NA	43.9	Unknown	NA	--
370	239.6	232.5	NA	7.1	Unknown	NA	Fault Zone/rising water
380	239.6	233.5	NA	6.1	Unknown	NA	Fault Zone/rising water
390	239.6	234.5	NA	5.1	Unknown	NA	Fault Zone/rising water
400	239	236.5	NA	2.5	Unknown	NA	Fault Zone/rising water
410	239	233.5	NA	5.5	Unknown	NA	Fault Zone/rising water
420	239	231.5	NA	7.5	Unknown	NA	Fault Zone/rising water
425	238.6	230.5	164.3	8.1	66.2	74.3	Valmonte Present
430	238.6	230.5	168.3	8.1	62.2	70.3	Valmonte Present
440	238.6	230.5	171.4	8.1	59.1	67.2	Valmonte Present
450	238.6	231	171.4	7.6	59.6	67.2	Valmonte Present
460	238.6	230.5	170.9	8.1	59.6	67.7	Valmonte Present
470	238	230.5	171.4	7.5	59.1	66.6	Valmonte Present
480	238	230.5	171.4	7.5	59.1	66.6	Valmonte Present
490	238	230.5	184	7.5	46.5	54	Valmonte Present
500	238.2	231.5	189.6	6.7	41.9	48.6	Valmonte Present
510	238.2	232.5	189.6	5.7	42.9	48.6	Valmonte Present
520	238.6	234	189.1	4.6	44.9	49.5	Valmonte Present
530	238.7	232.5	189.1	6.2	43.4	49.6	Valmonte Present
540	239	233.6	189.7	5.4	43.9	49.3	Valmonte Present
550	239.7	232.1	184.1	7.6	48	55.6	Valmonte Present
560	240.1	230.6	181.6	9.5	49	58.5	Valmonte Present
570	240.7	229.1	180.1	11.6	49	60.6	Valmonte Present
580	241.1	230.6	178.6	10.5	52	62.5	Valmonte Present
590	241.2	232.1	177.6	9.1	54.5	63.6	Valmonte Present
600	241.7	212.9	174.5	28.8	38.4	67.2	Valmonte Present
610	242.2	213.9	168.5	28.3	45.4	73.7	Valmonte Present
620	242.7	220.5	162.9	22.2	57.6	79.8	Valmonte Present
630	242.7	223	160	19.7	63	82.7	Valmonte Present

Table 5: B-B' Groundwater Elevations and Feature Depths

Station (feet)	**Surface Elevation (feet MSL)**	**Groundwater Elevation (feet MSL)**	**Bottom of Water/top of Impermeable unit** (feet MSL)	**Depth to Water (feet bgs)**	**Thickness of Water Zone (feet)**	**Depth to Impermeable Unit (feet bgs)**
240	245.2	197.2	NA	48	Unknown	NA
250	244.2	225.5	NA	18.7	Unknown	NA
260	242.7	230	NA	12.7	Unknown	NA
270	240.9	236.4	209	4.5	27.4	31.9
280	240	226.8	214.2	13.2	12.6	25.8
290	239.5	233.4	203.6	6.1	29.8	35.9
300	238.9	231.9	190.5	7	41.4	48.4
310	238.5	229.9	190.5	8.6	39.4	48
320	237.5	228.4	209.1	9.1	19.3	28.4
330	236	226.8	187.9	9.2	38.9	48.1
340	234.4	226.3	190.9	8.1	35.4	43.5
352	233.4	231.4	195.5	2	35.9	37.9
360	232.4	225.3	194	7.1	31.3	38.4
370	230.9	221.3	194.5	9.6	26.8	36.4
380	229.4	219.3	194.5	10.1	24.8	34.9
390	228.4	219.3	193	9.1	26.3	35.4
400	227.4	218.8	191.5	8.6	27.3	35.9
406	226.4	223.3	193.5	3.1	29.8	32.9
410	225.8	218.7	195.5	7.1	23.2	30.3
420	224.8	214	205	10.8	9	19.8
430	223.8	213.7	NA	10.1	Unknown	NA
440	222.8	213.2	NA	9.6	Unknown	NA
450	221.8	203.6	NA	18.2	Unknown	NA
460	220.8	205.1	146	15.7	59.1	74.8
470	219.3	204.1	181.9	15.2	22.2	37.4
480	218.3	203.6	179.9	14.7	23.7	38.4
490	216.7	204.6	185.4	12.1	19.2	31.3
500	215.7	198	186.9	17.7	11.1	28.8
505	214.7	195.5	190.9	19.2	4.6	23.8

4. DISCUSSION AND RECOMENDATIONS

The following sections describe an updated conceptual hydrogeology model and provide general recommendation for engineering solutions to manage groundwater seepage into the Malaga Cove Plaza buildings.

4.1 Revised Conceptual Hydrogeology Model Narrative

Building on the conceptual hydrogeology model developed by Chang (2001) (Figure 13) and incorporating information and evaluations from Sections 2.2 to 2.8, along with interpreted electrical resistivity surveys (Section 3), the following sections provide updated groundwater flow paths potentially affecting the Malaga Cove Plaza area.

Precipitation falls on permeable surface soils at higher elevations in the watershed and flows north toward Malaga Creek and Malaga Cove Plaza. It follows surface drainage pathways, accumulating in natural basins. This water then infiltrates into water-bearing geologic units or dune sands, combining with upwelling groundwater along subvertical fault lines near the intersection of Via Chico and Via Campesina (Figures 16 and 17).

Groundwater moves north toward Malaga Cove Plaza and Malaga Creek, leading to seepage into the buildings due to elevated groundwater levels from fresh and brackish groundwater upwelling. Most groundwater seepage appears to originate subsurface, with a brackish source on the south side of the fault block and fresh water combining on the north side. The fault block footprint closely overlaps with many known well seep locations (Figures 12 and 17).

Areas along or south of Via Campesina do not exhibit visually noticeable groundwater seepage because these areas do not appear to be underlain by the fault block footprint and its associated sandy units.

4.2 Engineering Mitigation Options

The interpreted fault block shown in Figure 17, along with the groundwater elevations and geologic feature depths detailed in Tables 4 and 5 for A-A’ and B-B’, can be used to determine the approximate extent and depth of engineering mitigation options for groundwater management.

Preliminary extent of potential engineering mitigation options that can installed to capture and convey groundwater are described below.

4.2.1 Via Campesina Mitigation

A horizontal well or sub-drain system along Via Campesina should extend from Stations 370 to 700 along the A-A’ transect, with screened or open intervals from 6 to 20 feet bgs, or deeper if feasible based on water level depths and geologic contacts from A-A’ Stations 370 to 570. This distance is the minimum needed to capture water along the A-A’ transect. The target depths are also supported by the water depths indicated for Stations 270 to 450 along the B-B’ transect (Table 4).

4.2.2 Malaga Lane Mitigation

The horizontal well or sub-drain system should extend across the interpreted fault block, with screened depths or open intervals below the existing drainage system along Malaga Lane. These wells or sub-drains should span the equivalent distance of A-A’ Stations 200 to 700 (Via Campesina), covering approximately 350 feet across the fault block, starting from the northeast side of Via Chico, and extending west along Malaga Lane. The vertical depths of the horizontal wells or sub-drains should be 10-25 feet bgs, based on the data from B-B’ Stations 430 to 450 and below basement and foundation elevations for existing buildings.

4.3 Recommendations

The following recommendations are provided to develop engineering mitigation to control groundwater seepage into the Malaga Cove Plaza buildings:

4.3.1 Preliminary Engineering Design and Engineers Cost Estimate

Feasibility and preliminary engineering design of a horizontal well or sub-drain system should be conducted to assess the viability of the selected engineering mitigation. This process, in general, should include:

- System Design and Layout:
    - Determination of the optimal location, alignment, and depth of horizontal wells or sub-drains utilizing the information discussed Section 3 and 4.2.
    - Design of well screens or perforated pipe sections to maximize water capture.
    - Specification of the horizontal distance and vertical depth of the system based on the information discussed Section 3 and 4.2.
- Hydraulic and Capacity Analysis:
    - Calculation of the expected inflow rates and the capacity of the dewatering system.
    - Analysis of the hydraulic gradient and the flow rate of groundwater towards the system.
    - Ensuring the system can handle peak inflow conditions and prevent groundwater accumulation.
- Material Selection:
    - Selection of appropriate materials for pipes, screens, and filters to withstand site-specific conditions.
    - Consideration of corrosion resistance, durability, and compatibility with the groundwater chemistry.
- Construction Methods and Feasibility:
    - Evaluation of feasible construction techniques for installing horizontal wells or sub-drains, such as trenching or directional drilling.

  - Assessment of site access, logistical constraints, and potential impacts on existing structures.
  - Estimation of construction timelines and costs.
- Discharge and Treatment:
  - Design of discharge points, sump locations, and conveyance systems to manage collected water.
  - Consideration of treatment options for extracted water if it contains contaminants.
  - Compliance with local regulations and environmental standards for water discharge.
- Monitoring and Maintenance:
  - Development of a monitoring plan to track the performance of the dewatering system.
  - Implementation of maintenance schedules to ensure the system remains effective and operational.
  - Installation of monitoring wells and instrumentation to measure groundwater levels and flow rates.
- Environmental and Regulatory Considerations:
  - Assessment of potential environmental impacts of the dewatering system.
  - Obtaining necessary permits and approvals from relevant authorities.
  - Ensuring the design complies with environmental regulations and guidelines.
- Cost-Benefit Analysis:
  - Evaluation of the overall cost-effectiveness of the dewatering system.
  - Comparison of different design alternatives and their associated costs and benefits.
- Potential Risk Assessment:
  - Identification of potential risks associated with the construction and operation of the dewatering system.
  - Development of mitigation strategies to address identified risks.
  - Consideration of long-term sustainability and potential changes in site conditions.

4.3.2 Research Utility Partnerships and Funding Opportunities

To identify utility partnerships and potential funding sources for the feasibility and preliminary engineering design of a horizontal well or sub-drain system, the City can perform research of local, regional, and State utilities that may be interested in groundwater management, infrastructure improvements, or environmental protection. Presenting the project's goals and expected outcomes will help align with these utilities' objectives and explore opportunities for collaboration, such as joint funding and resource sharing.

The City should also identify potential funding sources, including government grants, loans, and subsidies from federal, State, and local agencies. Preparing comprehensive grant applications that highlight the project's objectives, benefits, and alignment with funding agency goals is crucial. Leveraging existing utility programs that offer financial assistance for infrastructure projects or water management can also be beneficial.

Geosyntec staff can provide administrative and technical support to secure partnerships and identify funding opportunities, as well as assist in the application process for potentially available funding sources

4.3.3 Collect Groundwater Seep Samples

As discussed in Section 2.10.2, the source of groundwater seeping into the Malaga Cove Plaza buildings year-round, including during summer, is currently unknown. Recent information suggests the water may be upwelling from both fresh and brackish sources. To verify groundwater sources, samples from known and accessible seepage location should be collected and analyzed in the laboratory. This analysis should include testing for cations and anions, total dissolved solids, pH, conductivity, metals, and other relevant parameters. The results should then be plotted and compared to the chemical signatures of known water sources, such as California State Water Project water and seawater. Geosyntec can develop a sample collection plan that includes cost and evaluation. The primary benefit of this analysis would be to confirm if the groundwater sources are indeed fresh and brackish.

4.4 Conclusions and Limitations

The geologic interpretations made during this investigation, as indicated in Figures 15 and 16, are primarily based on resistivity data, experience, and assumptions from previously mapped units by Cleveland (1976) and Dibblee (1999). No direct observation or verification of the depth to the Valmonte Diatomite or Altamira Shale was conducted during this survey. Geosyntec and Spectrum Geophysics provide no warranty, express or implied, that these specific geologic units or the precise contacts of the Monterey Formation are present at the indicated depths and elevations in Figures 15 and 16 or Tables 4 and 5.

All hydrogeologic and geologic information, conclusions, and recommendations in this document have been prepared under the supervision of, and reviewed by, a California Professional Geologist. A professional geologist's certification of conditions represents their professional judgment and does not constitute a warranty or guarantee.

5. REFERENCES

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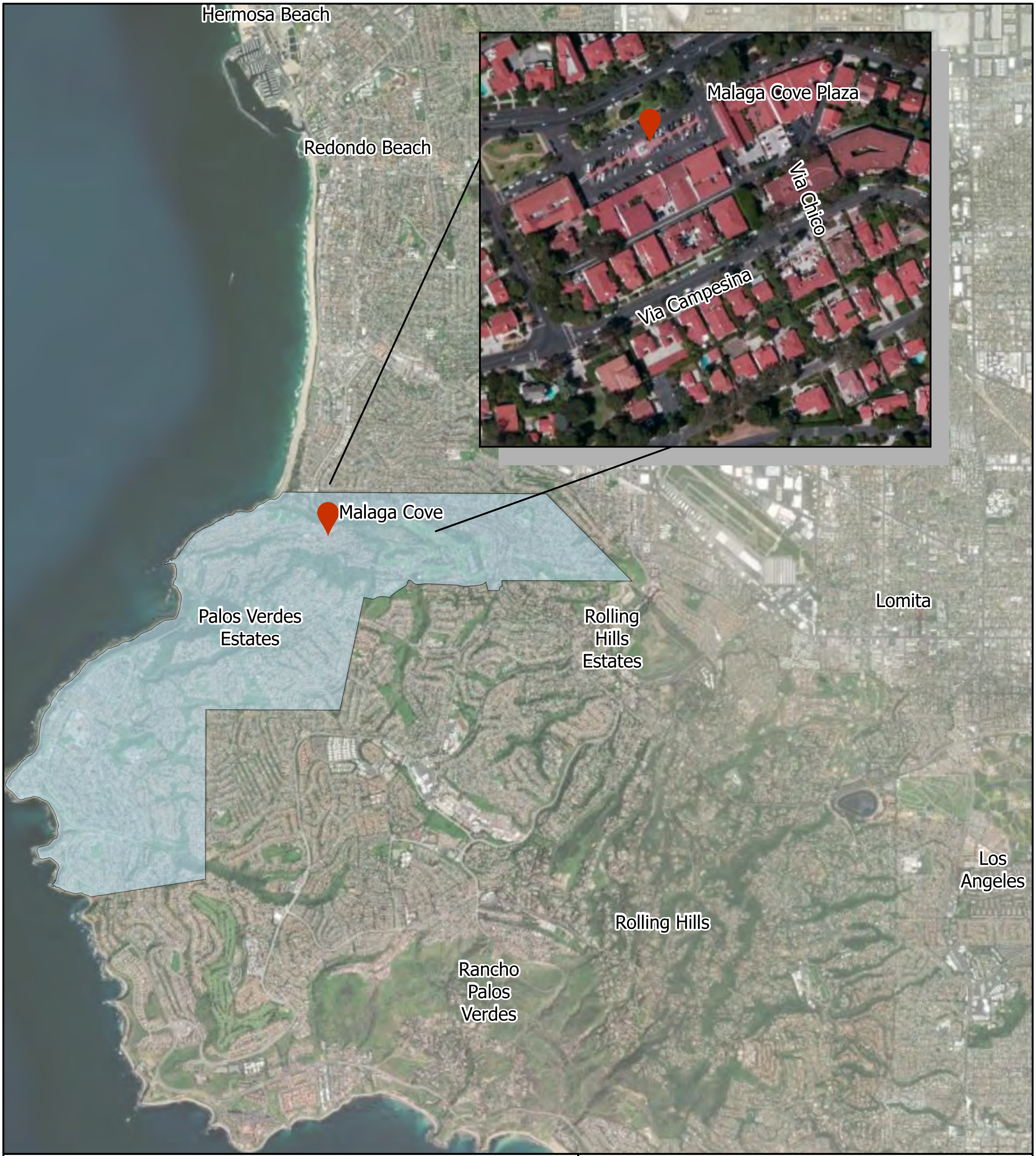
FIGURES



Legend

📍 Malaga Cove

🟦 Palos Verdes Estates City Limit

N

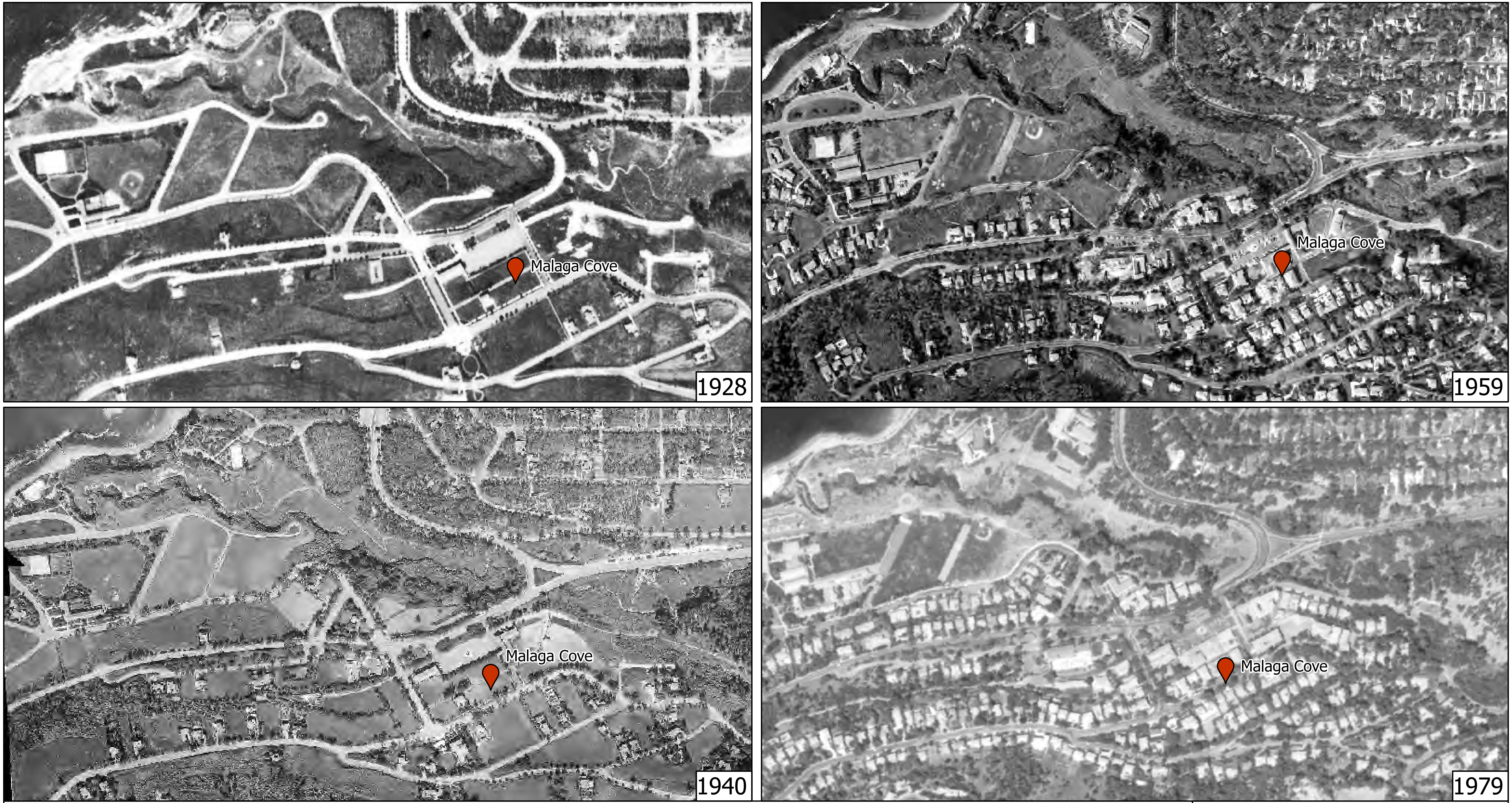
0 4,000 Feet

Site Location Map

Malaga Cove Plaza Area
Palos Verdes Estates, CA

Geosyntec consultants

SC1425	June 2024	**Figure** 1



Legend

📍 Malaga Cove

Historical Aerial Photos

Malaga Cove Plaza Area
Palos Verdes Estates, CA

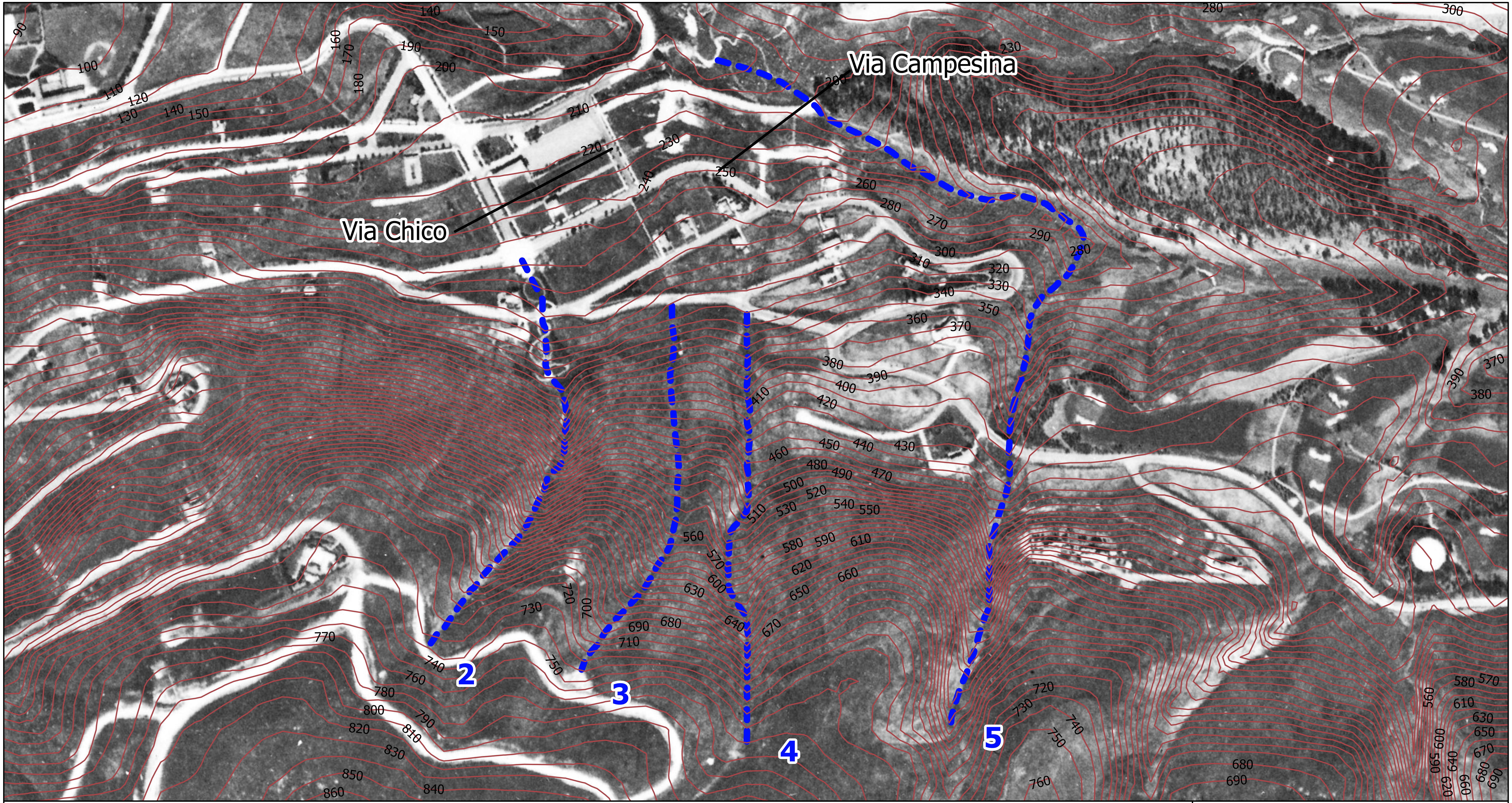
Geosyntec consultants

SC 1425

June 2024

Figure

2



Legend

- Surface Drainages 1928
- Elevation Contours (mean sea level)

Source: University of California, Santa Barbara. (n.d.). Framefinder. Flight C-300. Retrieved May, 2024, from https://mil.library.ucsb.edu/ap_indexes/FrameFinder

N

0 460 Feet

Surface Drainages 1928

Malaga Cove Plaza Area
Palos Verdes Estates, CA

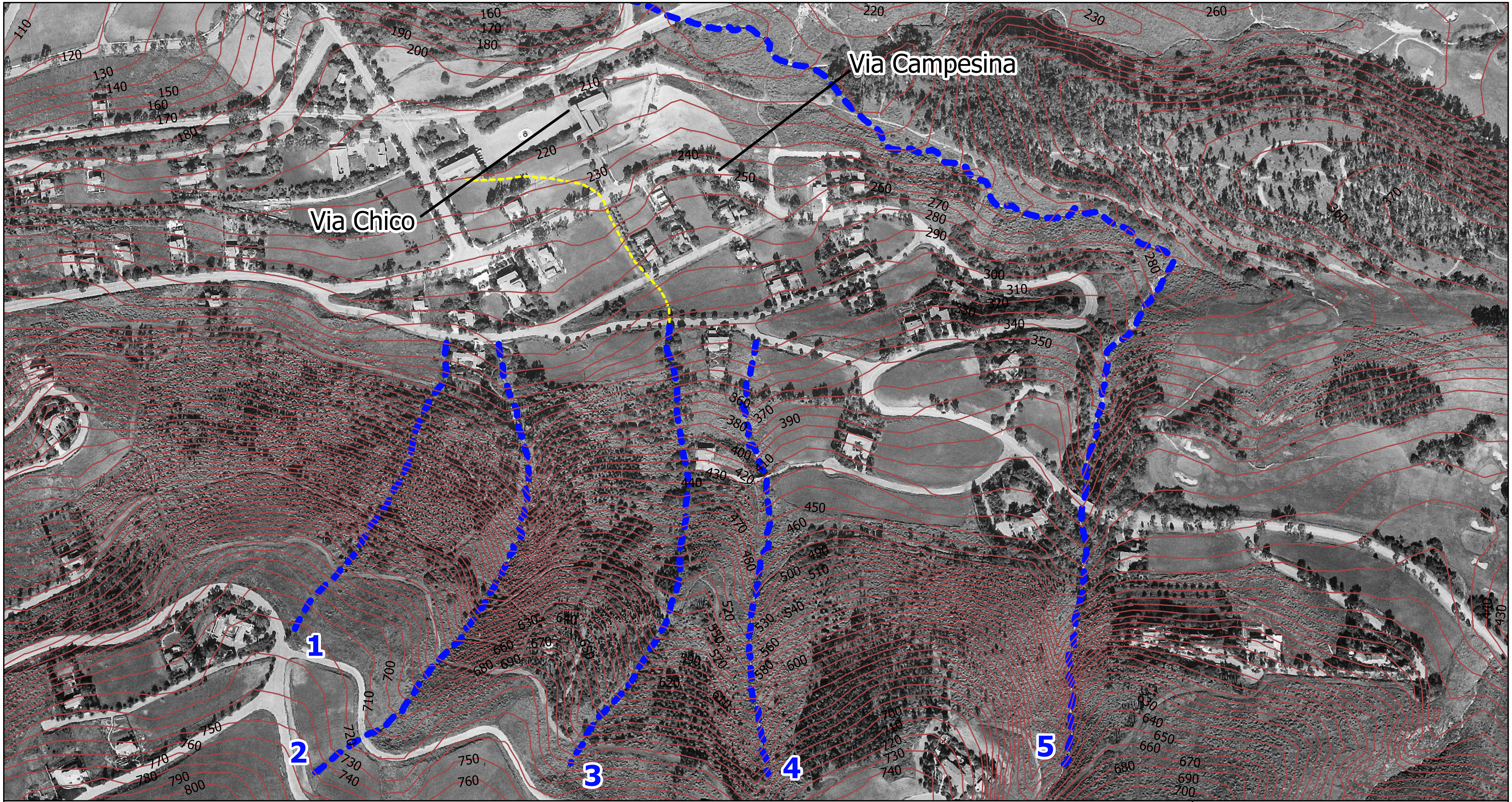
Geosyntec consultants

SC1425 June 2024

Figure

3

P:\GIS\SC1425\Palos Verdes Estates\Palos Verdes Estates.aprx\Figure 3 - Annotated Aerial Photo 1928 6/14/2024 1:26 PM (James.Gonzales)



Legend

▬ Surface Drainages 1940

┅ Extension of Drainage 3

─ Elevation Contours (mean sea level)

Source: University of California, Santa Barbara. (n.d.). Framefinder. Flight C-6330. Retrieved May, 2024, from https://mil.library.ucsb.edu/ap_indexes/FrameFinder

N

0 360 Feet

Surface Drainages 1940

Malaga Cove Plaza Area
Palos Verdes Estates, CA

Geosyntec
consultants

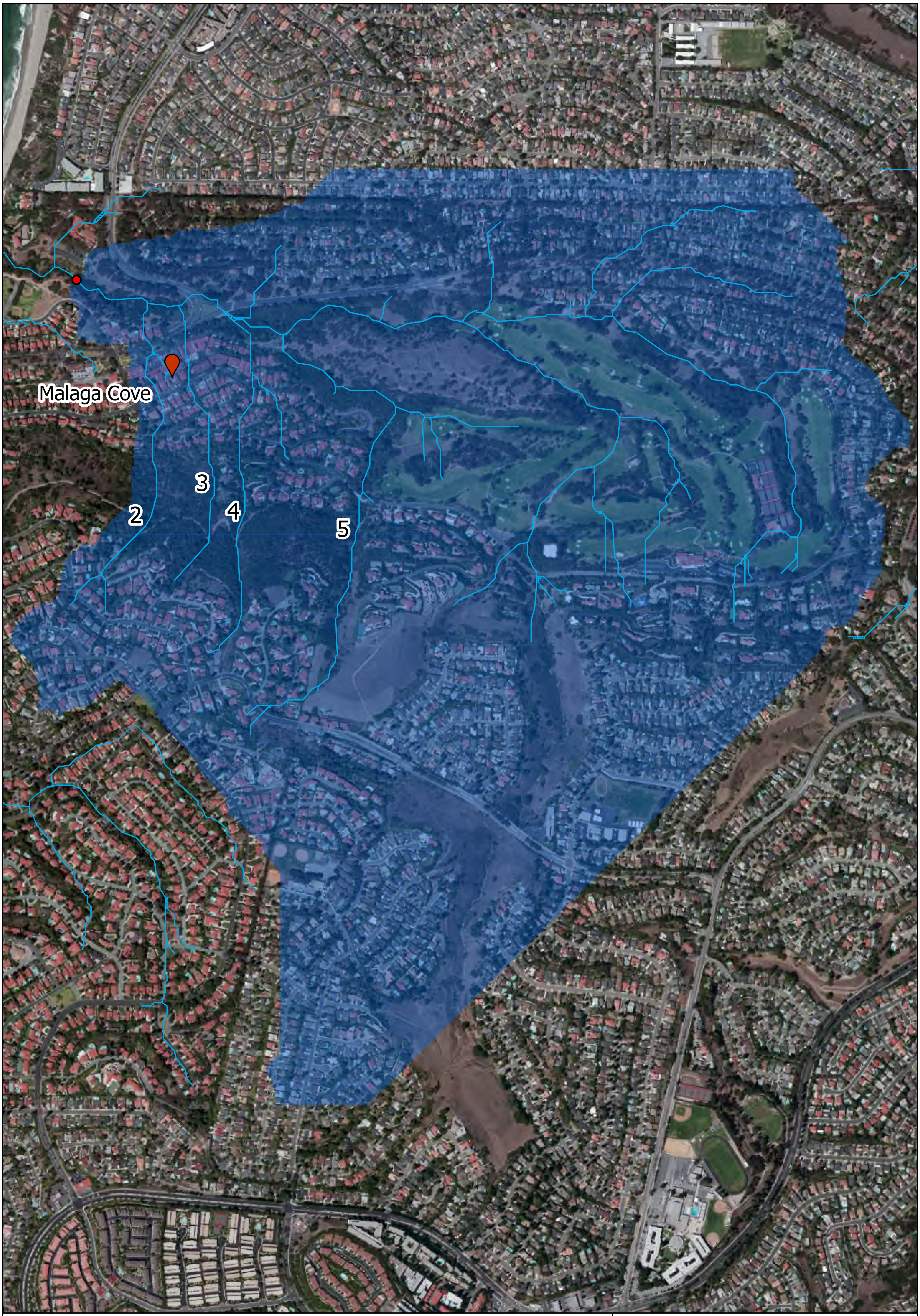
Figure

4

SC1425

June 2024

P:\GIS\SC1425\Palos Verdes Estates\Palos Verdes Estates.aprx\Figure 4 - Annotated Aerial Photo 1940 6/14/2024 1:26 PM (James.Gonzales)



Legend

📍 Malaga Cove

— Surface Drainages or Streams

Watershed Boundary

▨

N

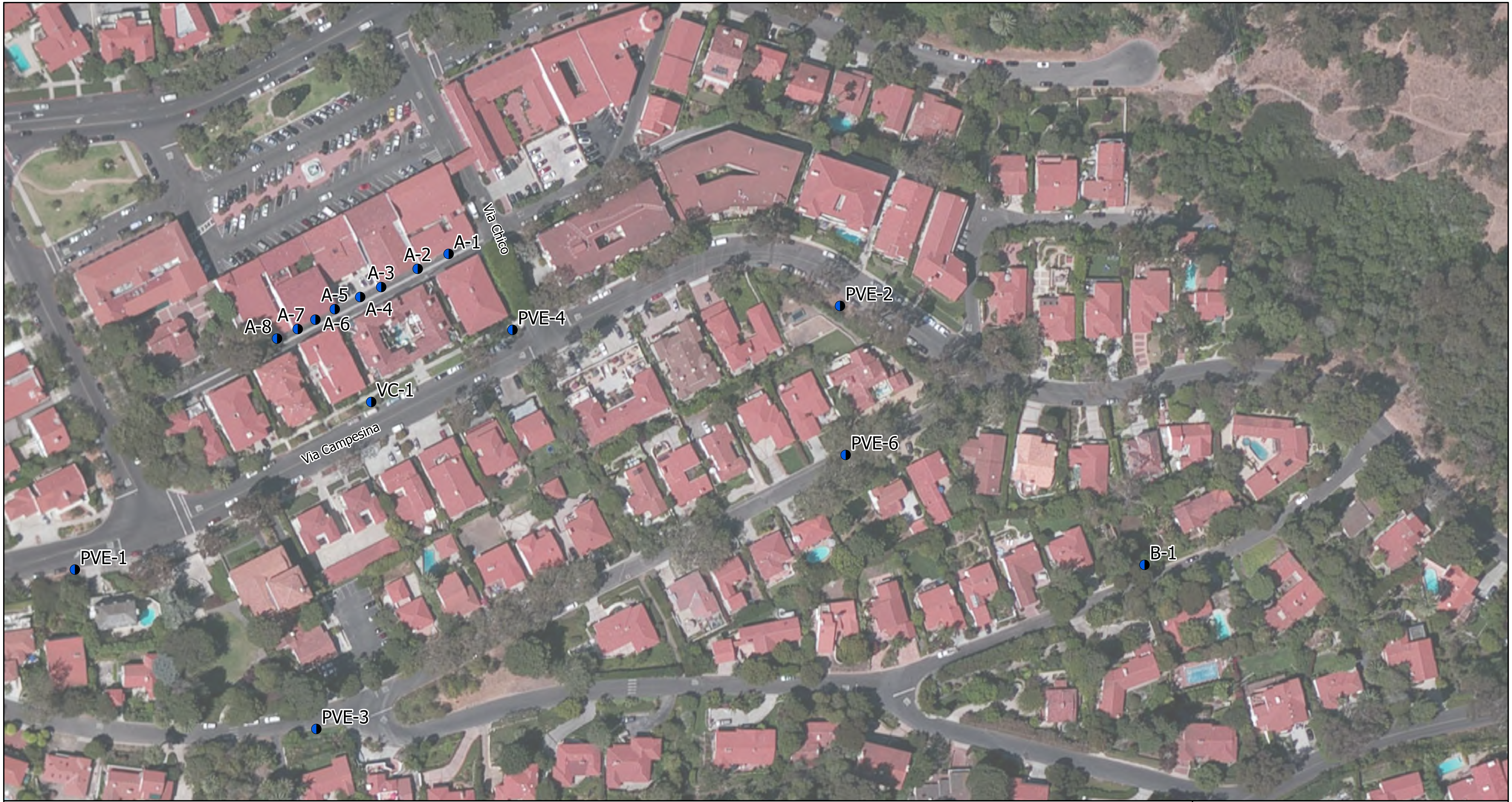
0 800 Feet

Watershed Analysis

Malaga Cove Plaza Area
Palos Verdes Estates, CA

Geosyntec consultants

SC1425	June 2024	**Figure** 5



Legend

◐ Existing Monitoring Wells

N

0 100 Feet

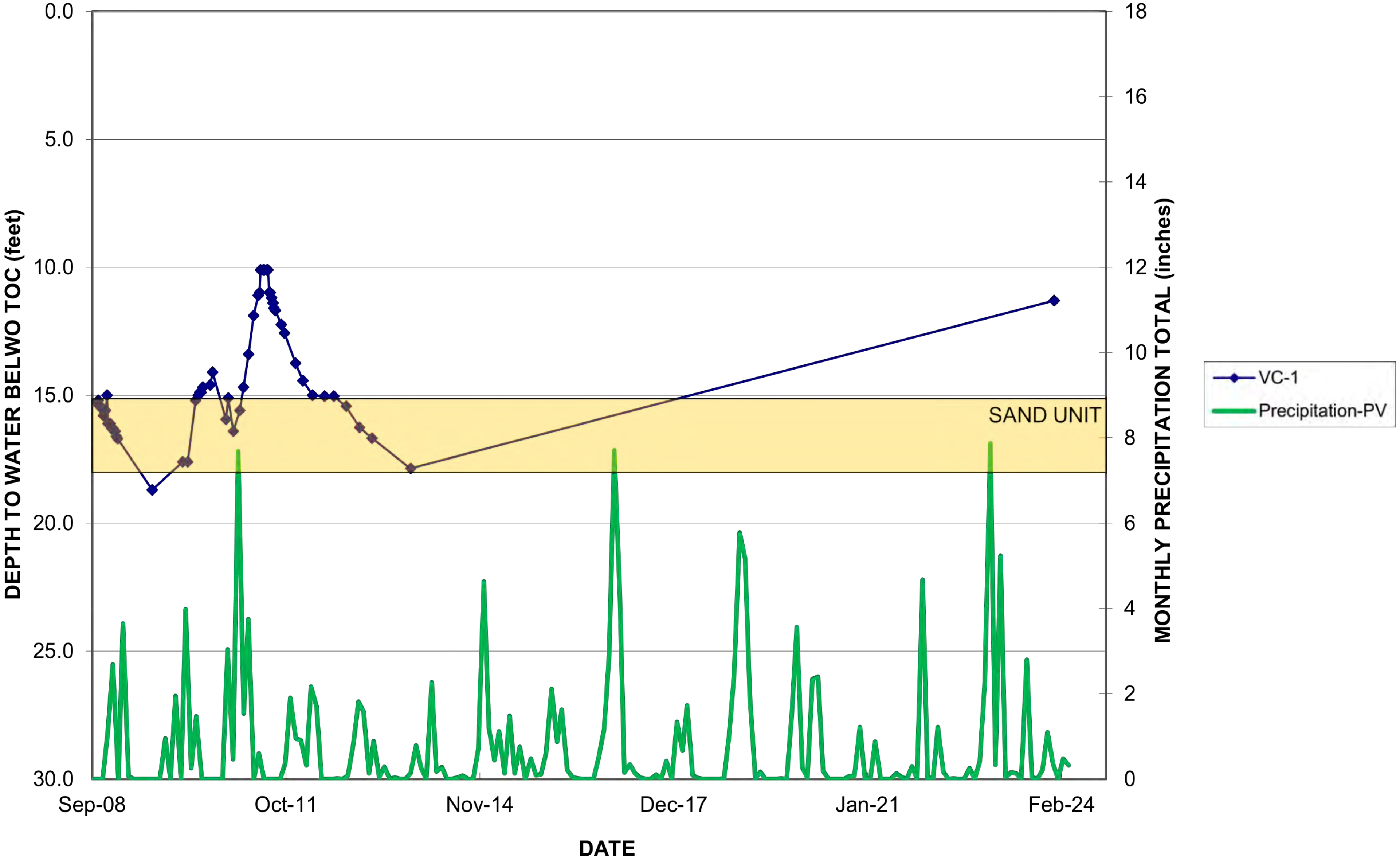
Palos Verdes Estates Groundwater Monitoring and Dewatering Wells

Malaga Cove Plaza Area
Palos Verdes Estates, CA

Geosyntec consultants

SC1425	June 2024	**Figure** 6

P:\GIS\SC1425\Palos Verdes Estates\Palos Verdes Estates.aprx\Figure 6 - Palos Verdes Estates Well Locations 6/14/2024 10:04 AM (Mark.Pratt)



VC-1 Depth-to-Groundwater Measurements

Malaga Cove Plaza Area
Palos Verdes Estates, CA

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Figure

7

SC1425

June 2024

Legend

◐ Existing Monitoring Wells
🟩 Qal (Alluvial Deposits)
🟦 Qs (Lagoon, Beach, and Dune Sands)
🟪 Qsw (Slump, Creep, and Slope Wash Deposits)
🟥 Qter (Terrace Deposits)

Source: Cleveland, G.B., 1976, Map sheet 27, plate 1: Geologic map of the northeast part of the Palos Verdes Hills, Los Angeles County, California IN: Geology of the northeast part of the Palos Verdes Hills, Los Angeles County, California: California Division of Mines and Geology, Map Sheet 27, scale 1:12000.

N

0 140 Feet

Surficial Geology

Malaga Cove Plaza Area
Palos Verdes Estates, CA

Geosyntec
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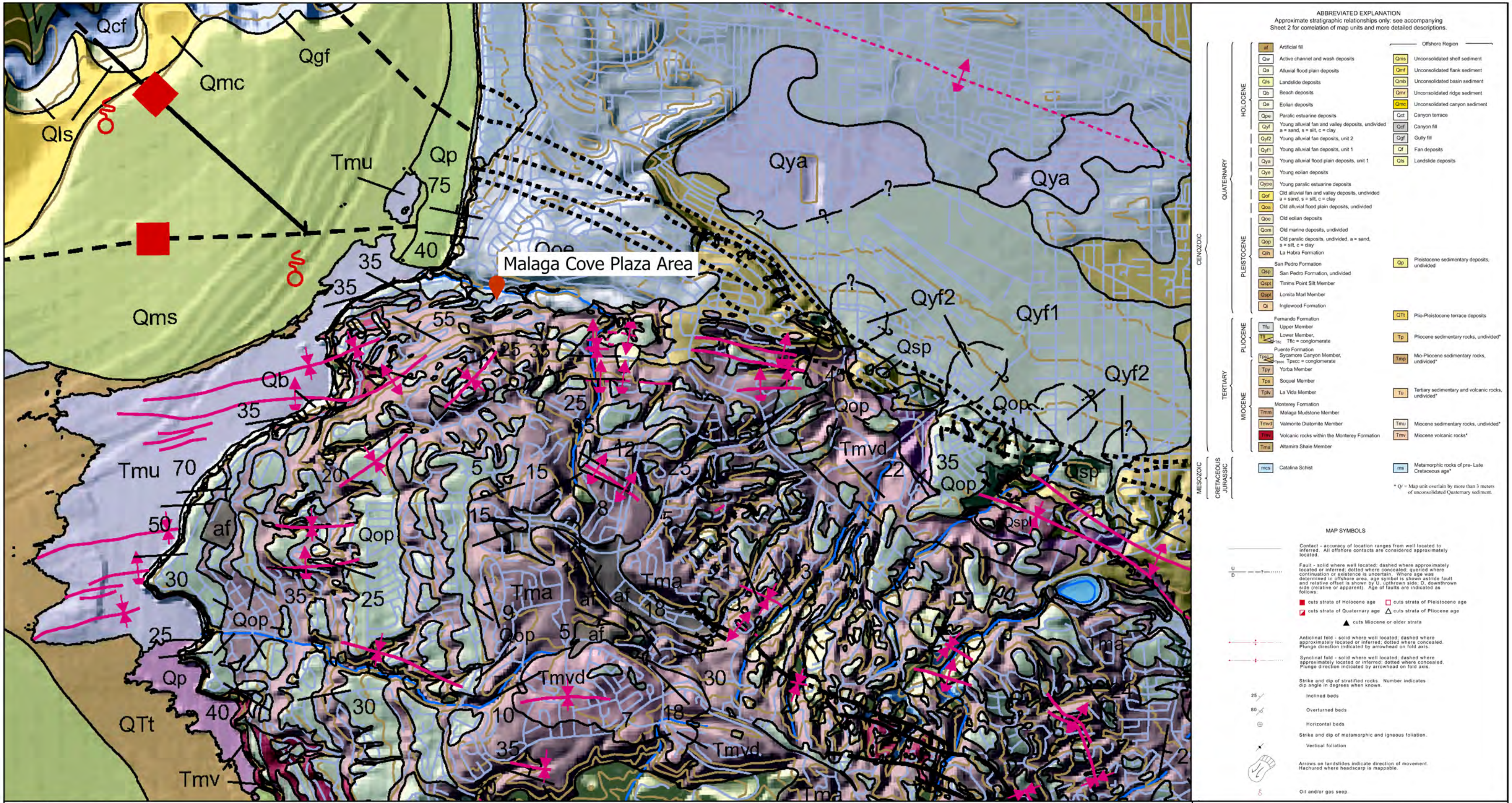
SC1425 | June 2024

Figure

8



Legend

Malaga Cove

N

0 2,000 Feet

Regional Geology

Malaga Cove Plaza Area
Palos Verdes Estates, CA

Geosyntec consultants

SC1425	June 2024

Figure

9

Legend

— Storm Drains

- - Natural Drainages

Source: Palos Verdes Estates Public Works

Existing Drain Infrastructure

Malaga Cove Plaza Area
Palos Verdes Estates, CA

Geosyntec
consultants

SC1425

June 2024

Figure

10

Legend

━ Storm Drains

N

0 220 Feet

Chico Path Storm Drains and Infrastructure

Malaga Cove Plaza Area
Palos Verdes Estates, CA

Geosyntec consultants

SC1425	June 2024	**Figure** 11

Legend

▲ Known Seepage Locations

Known Groundwater Seepage Locations

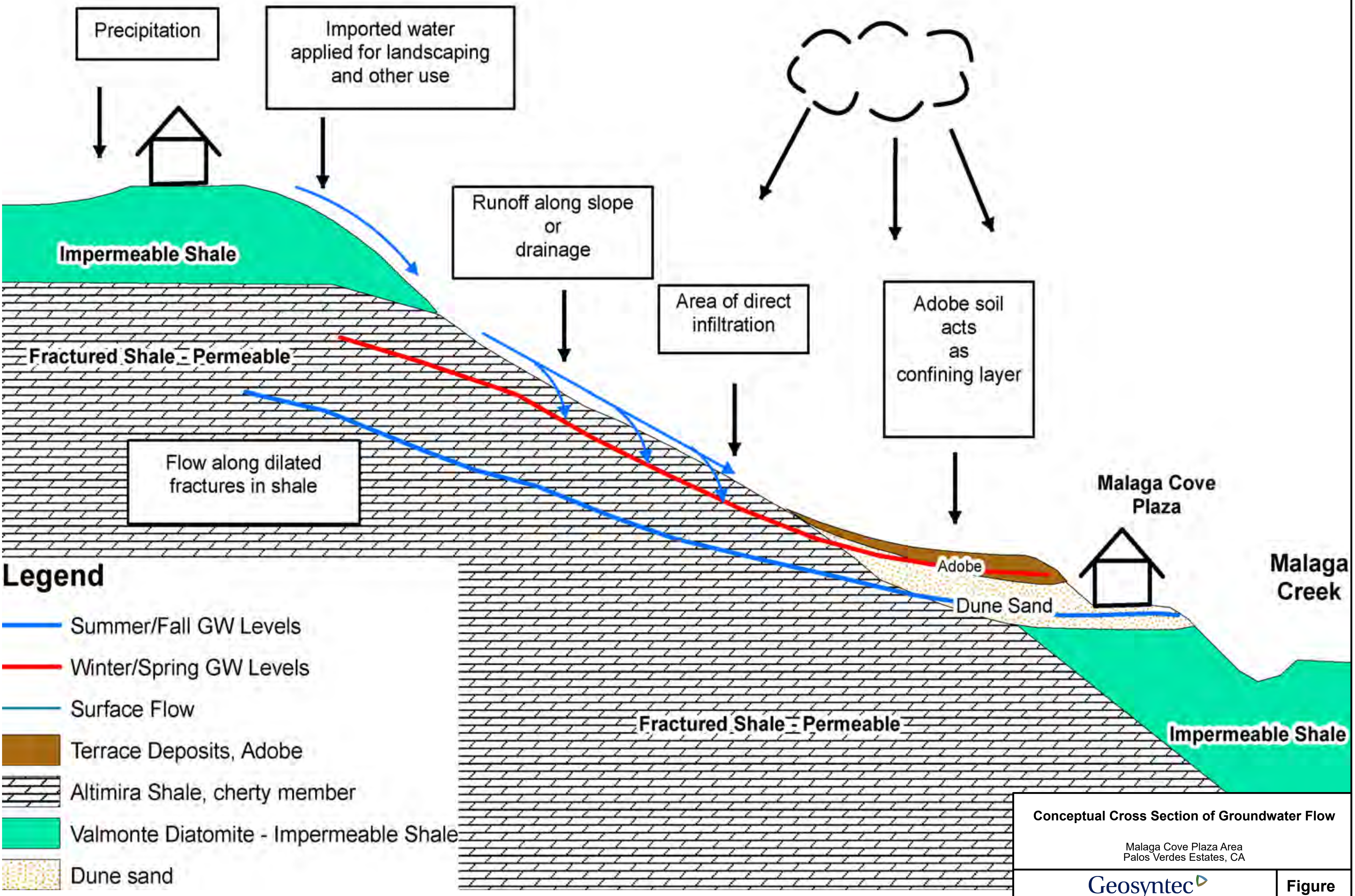
Malaga Cove Plaza Area
Palos Verdes Estates, CA

Geosyntec consultants

Figure 12

SC1425

June 2024



Source: Modified from Chang, 2001.

Conceptual Cross Section of Groundwater Flow

Malaga Cove Plaza Area
Palos Verdes Estates, CA

Geosyntec consultants

SC1425 June 2024

Figure 13

Legend

- ▲ Reported Groundwater Seep Locations
- ● Existing Monitoring Wells
- ━ Resistivity Transects

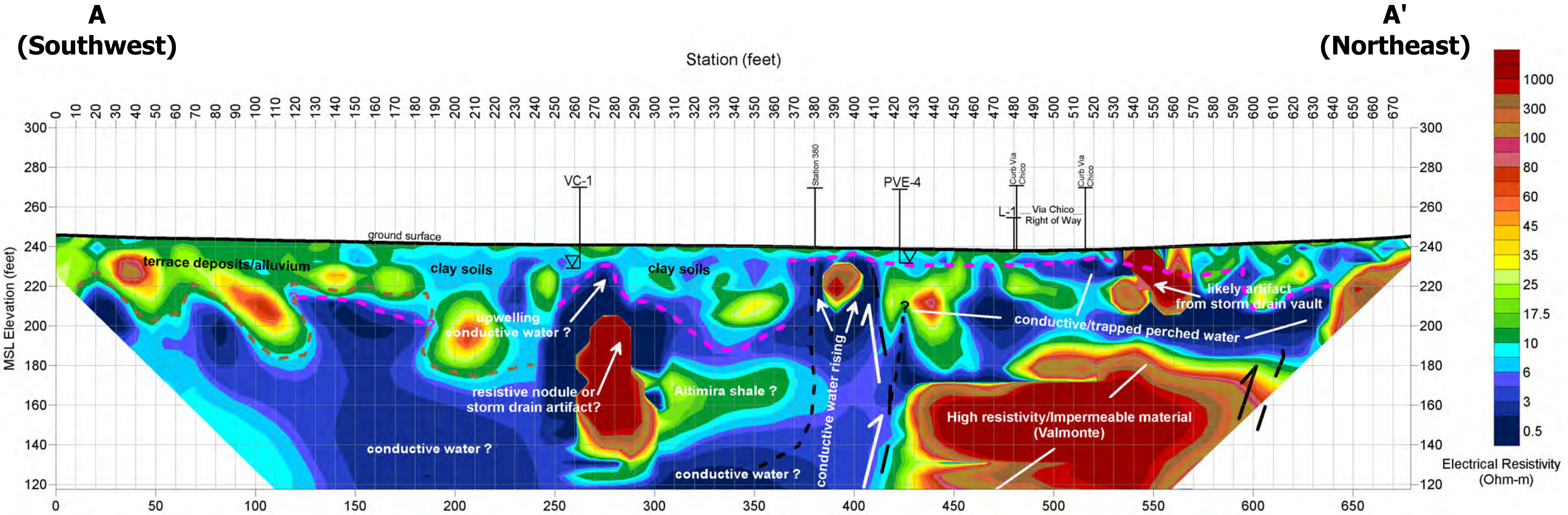
Geophysical Electrical Resistivity Transect Locations

Malaga Cove Plaza Area
Palos Verdes Estates, CA

Geosyntec consultants

SC1425	June 2024

Figure 14



Legend

▽ Approx. level of groundwater on 1/9/2024

Top of water bearing zone (interpreted)

Base of terrace deposits (interpreted)

Geologic Fault - Arrow indicates sense of movement (interpreted)

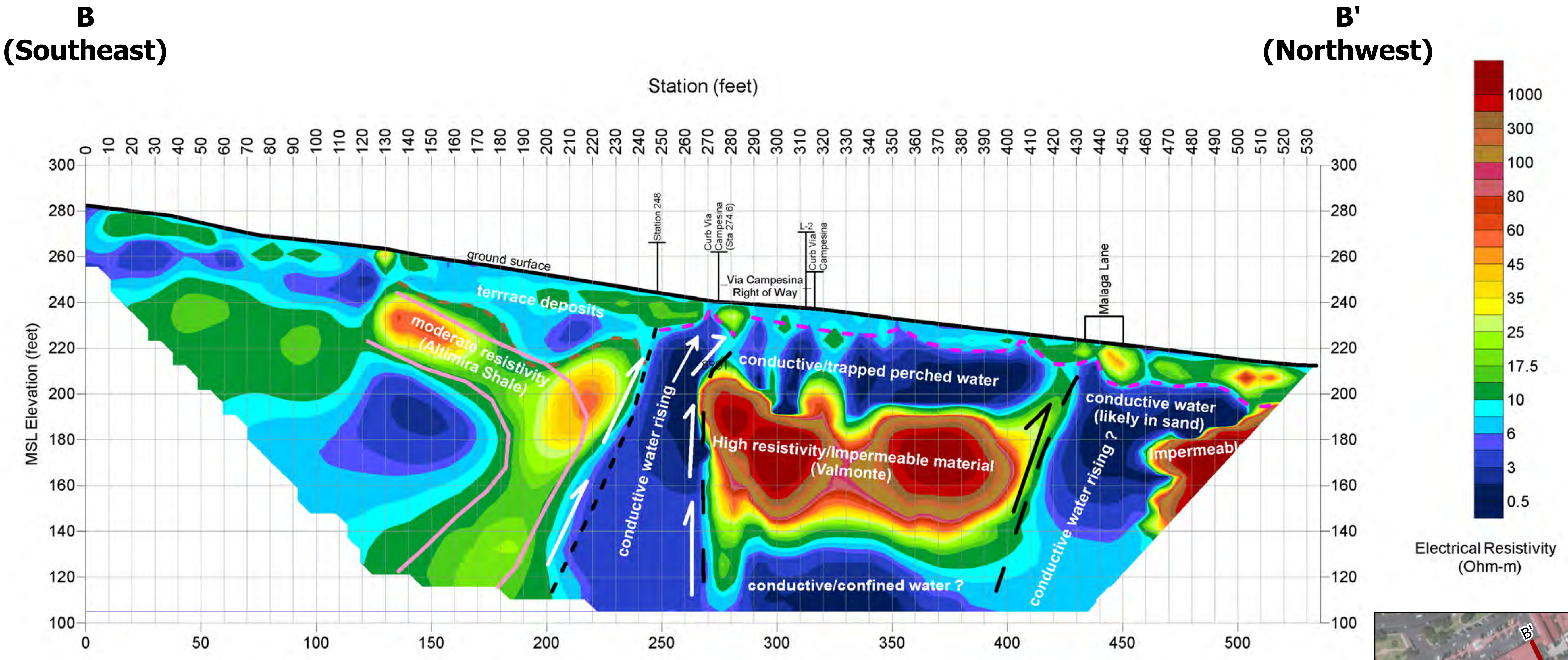
Geophysical Electrical Resistivity Cross Section A-A' along Via Campesina

Malaga Cove Plaza Area
Palos Verdes Estates, CA

Geosyntec consultants

SC1425 | June 2024

Figure 15



Legend

Top of water bearing zone (interpreted)

Geologic Fault - Arrow indicates sense of movement (interpreted)

Geophysical Electrical Resistivity Cross Section B-B' along Via Chico

Malaga Cove Plaza Area
Palos Verdes Estates, CA

Geosyntec consultants

SC1425	June 2024	**Figure** 16

Legend

- \ Cross Section Station No.
- ▲ Reported Groundwater Seep Locations
- ● Existing Monitoring Wells
- — Resistivity Transects
- ▨ Fault Block (Interpreted)

N

0 60 Feet

Interpreted Fault Block

Malaga Cove Plaza Area
Palos Verdes Estates, CA

Geosyntec consultants

SC1425	June 2024	Figure 17

APPENDIX A

Spectrum Geophysics

Summary Report – Geophysical Investigation

SPECTRUM GEOPHYSICS, 16691 GOTHARD STREET, SUITE L, HUNTINGTON BEACH, CALIFORNIA 92647

June 5, 2024

Mr. James Gonzales
Geosyntec
3530 Hyland Ave., Suite 100
Costa Mesa, California 92626

RE: Summary Report - Geophysical Investigation
Malaga Cove Plaza and Vicinity
Via Chico at Via Campesina
Palos Verdes Estates, California

Dear Mr. Gonzales:

A geophysical investigation was conducted by Spectrum Geophysics (Spectrum) from April 22nd-26th, 2024 in the vicinity of Malaga Cove Plaza in Palos Verdes Estates, California (hereinafter referred to as the Property). The purpose of this investigation was to assist Geosyntec with delineation and imaging of subsurface features that may be controlling the flow of, or confining, groundwater in the area of Malaga Cove Plaza. Based on discussions with Geosyntec, Spectrum understands that residents at the Property have been experiencing systemic basement flooding for years (regardless of weather patterns) – and that this flooding has gotten worse in the past few years. As Geosyntec has been hired by the City of Palos Verdes (the City) to assist in mediating this situation, this geophysical investigation was designed to assist Geosyntec with delineation of suspected ephemeral/old surface drainages that are currently blocked, or possible subsurface geologic/hydrogeologic units or structural features that are confining groundwater at the Property. Accordingly, Spectrum was contracted to provide an image of these subsurface features to at least 60 feet along two orthogonal transects (Line 1 and Line 2) roughly centered at the intersection of Via Chico and Via Campesina at the Property (Figure 1). The geophysical method used to accomplish these goals was DC electrical resistivity.

To employ 2D electrical resistivity, a DC circuit is established in the ground via cables and a linear array of electrodes. During data collection a known amount of current is applied to the ground through a pair of electrodes (current electrodes), the voltage is read between another pair of electrodes (potential electrodes) some distance from the current electrodes, and the ground acts as the resistor to complete the circuit. Ohm's Law (V=IR) is then used to calculate the electrical resistance of the ground through which the current has traveled (termed electrical resistivity). The measured electrical resistivity values are then used to interpret subsurface lithology and features of interest.

FIELD PROCEDURES

During this investigation electrical resistivity data were collected with an AGI SuperSting R8/IP automated resistivity system (SuperSting) with associated resistivity cabling. These data were collected along Lines 1 and 2 using a linear array of 56 electrodes spaced 3 meters apart and array geometries of both Schlumberger and dipole-dipole in order to obtain a 2D image of the subsurface materials along each line. The SuperSting is designed such that the data are collected in units of meters and subsequently converted to feet.

Line 1 ran southeast-northwest, was roughly parallel to Via Chico and was 165 ground meters (541.3 ground feet) in length. To extend this line as long as possible for greatest depth of detection, Line 1 originated (southeast end) at Chico Path at Via Pinale, ran down Chico path, crossed the intersection of Via Chico and Via Campesina, and then ran along the southwest side of Via Chico to its endpoint at the brick archway. Line 2 ran southwest-northeast along the northwest side of Via Campesina and was 216 ground meters (708.7 ground feet) in length. Line 2 began at Via Corta, extended across the intersection of Via Chico and Via Campesina, and continued (approximately) to the point where Via Campesina begins to bend to the southeast. These transects are shown in green in Figure 1.

Resistivity Data Collection along Line 2 (View to Southwest)

Because utilities were present along Lines 1 and 2 (particularly along Chico Path on Line 1 and through the intersection of Via Chico and Via Campesina for both lines), utilities were located and marked in the vicinity of the transects, and care was taken to offset electrode locations from utilities and utility vaults as much as possible to minimize the electromagnetic interference effects from these utilities. These precise offsets are not shown in Figure 1 but were used during the data processing to adjust electrode geometry as necessary.

Once the data were collected, elevations of each station along each line were surveyed by the Spectrum crew, and subsequently converted to MSL elevation with a bench tie provided by Geosyntec. Data files were downloaded to a laptop and saved for subsequent office processing. During office processing a resistivity geophysical inversion routine was utilized along each profile in order to obtain 2D models of the electrical resistivity distribution beneath the ground surface along Lines 1 and 2, to depths of at least 60 feet below ground surface, where possible. The electrical resistivity method is discussed further in the attached methods section.

PROJECT RESULTS

The geophysical interpretation map is presented in Figure 1; the locations of Lines 1 and 2 are indicated in green in this figure. The anomalies identified during the Phase I GPR survey at Malaga Plaza are overlaid on this map. The resultant electrical resistivity profiles for Lines 1 and 2 are presented in Figures 2 and 3, respectively. The colors in the resistivity profiles in Figures 2 and 3 represent resistivity values, where a "modified rainbow" color scheme was used to represent the variation in resistivity; this color scheme is shown on the right side of Figures 2 and 3, where the same color scheme was used for both profiles. In these figures the lowest resistivity values (representing the most electrically conductive materials) are colored the darkest blue color, and resistivity values increase, along with grain size of subsurface materials, as the colors change from blues to greens to yellows to orange to red/red brown to darkest red (highest resistivity). While the measured range of resistivity values is highly site specific, for this project the resistivity values ranged from 0.1 Ohm-meters (darkest blue) to 3,000 Ohm-meters and above (darkest red).

These resistivity values were interpreted for site lithology/geology and hydrogeologic features, such as permeable vs impermeable geologic units, based on correlations with available geologic maps and known hydrogeology at the Property. Once these correlations were made, the variation in resistivity along each profile was used to interpret the location of specific geologic units (such as sand vs shale), geologic structure and attitudes (such as dipping vs flat lying layers) and geologic/hydrogeologic contacts (such as terrace deposits overlying shale or dry soils underlain by saturated materials).

Based on review of the available geologic maps (Dibblee and Cleveland Geology), mapped geologic contacts through the Malaga Plaza area (Conrad and Ehlig), and known depths to groundwater provided by Geosyntec, in addition to observations during the field work, the following Site Specific interpretation of resistivity values for groundwater and lithology was generated for this project area:

- Resistivity values from 0.1 to 3 Ohm-meters (darkest blue) correspond to conductive groundwater
- Resistivity values from 3 to 7 Ohm-meters (blue to light blue) are likely soils with clay, or may be fractured shale where continuous
- Resistivity values from 8 to 30 Ohm-meters (green to yellow) are likely soils ranging from silt to sand, where resistivity increases with increasing percentage of sand, coarse grained material or fragments of shale in the soil. Where continuous these values could be associated with layers of various types of shale

- Resistivity values ranging from 30 to 70 Ohm-meters (yellow to orange) where continuous, may be associated with dry cherty or calcareous Altimira Shale or dry sand; where variable these values may be associated with moderate to coarse grained alluvium or terrace deposits
- Areas with resistivity values exhibiting a steep lateral or vertical gradient in resistivity, where values increase sharply from 60 (orange) to 300 (brown) to 1000 (dark red) and above Ohm-meters are interpreted as the Valmonte Diatomite unit of the Monterey Formation

Based on the above interpretations of resistivity and correlations across the profiles, the following has been interpreted, and is shown in Figure 1:

- A steeply south dipping/nearly vertical reverse fault/fault block, roughly 120 feet wide and oriented WNW-ESE, runs through the intersection of Via Chico and Via Campesina and extends to the WNW beneath a portion of Malaga Plaza. This fault/fault block may be a splay of, or associated with, the Redondo Canyon Fault Zone- which has been mapped offshore
- The Main Fault offsets the Altimira Shale (south side of fault) which is permeable, with the Valmonte Diatomite unit (north side of main fault), which is impermeable, and has caused shallow groundwater to be trapped or perched within the confines of the fault block
- The fault block appears to be bordered on either side by a vertically/sub vertically oriented fractured zone of conductive groundwater, which appears to be migrating vertically
- The data collected along Line 1 suggest that conductive groundwater may be confined beneath the Valmonte Diatomite at depth in the area of the fault block. As such, this water (perhaps under pressure) may be rising through the vertical/subvertical fractured zones

The interpretation of the fault/fault block was made primarily by the resistivity data/2D model profile for Line 1. These data were of higher quality than those collected along Line 2 (due to metallic utility interference along Line 2); in addition, Line 1 may have an orientation more closely aligned with perpendicular to geologic strike and the fault/fault block, which makes it easier to detect with DC resistivity. Key features identified on each transect are discussed briefly on a line by line basis below.

Line 1

The resistivity profile for Line 1 is presented in Figure 2. In this figure the numbers on the horizontal axis represent ground distance (Station) in feet along the line, and the numbers on the vertical axis are MSL elevations in feet. The data collected along Line 1 provide a depth of investigation of about 130 feet below ground surface (bgs) for the majority of the profile; however, there is a tapering effect loss of data at either end of the profile, which is a limitation of the DC resistivity method. Key surface features and tie points (such as the Via Campesina right of way and the boundaries of Malaga Lane), along with key interpreted geologic and hydrogeologic units, have been labeled on the profile in Figure 2.

Fault Block

The boundaries of the interpreted Main Fault on Line 1 are indicated with a heavy dashed black line in Figure 2. Based on the resistivity data, the feature here referred to as the "Main Fault" appears to offset the Altimira Shale unit of the Monterey Formation (to the south at a depth of about 22 feet bgs) with the Valmonte Diatomite unit (to the north at a depth of about 32 feet bgs), where a near-vertical, steeply south dipping zone of fractured saturated rock appears to be sandwiched in between these two units. The south end of the Main Fault projects to Station 274.6 on Line 1, where the vertical/subvertical zone of fractured saturated rock is evident between Stations 248 and 274.6 based on a vertical/subvertical zone of very low to low resistivity values (ranging from 0.1 to 3 Ohm-meters – darkest blue to deep blue) that appears to extend from depth. Based on these low resistivity values the water appears to be conductive and is likely high in TDS; based on the character of this low resistivity anomaly, the water appears to be rising vertically through the zone of fractured rock. South of this fractured zone (south of Station 248) the Altimira shale is interpreted based on a layer of laterally continuous moderate resistivity values, and appears to be overlain by lower resistivity soils or alluvium (likely terrace deposits).

Beginning at Station 270 the Valmonte Diatomite unit appears at a depth of about 32 feet bgs, based on the very high resistivity (500 to 3,000 Ohm-meters – brown to dark red) anomaly that is roughly 50 feet thick and extends to the north end of the fault block, which is marked by another reverse fault (at about Station 430). These high resistivity values indicate the Valmonte is impermeable, which creates a condition that appears to be causing groundwater to be perched above it. Based on the resistivity data, the top of the Valmonte contact is somewhat variable, but ranges between about 26 and 48 feet bgs, where it appears to be about 35 to 37 feet deep (in general) in the area of the fault block. As previously stated, the north end of the fault block projects to about Station 430 on Line 1, which is bounded by another steeply south dipping, apparently fractured and water-saturated zone. Based on the character of the resistivity data this zone may have conductive water migrating vertically/sub-vertically through it (particularly between Stations 430 and 440); it is interesting to note this feature lies beneath Malaga Lane, as shown in Figure 2. However, based on the resistivity values (5 to 7 Ohm-meters) below about 83 feet bgs this rising water may be either less conductive than the water on the south side of the fault block, or it does not extend to great depths. Because the data are less resolved at this depth this cannot be determined. Northwest of the fault block the Valmonte appears to be absent, where the second reverse fault (projecting to Station 430) is interpreted to offset Valmonte to the south against saturated dune sand to the north. Beginning at about Station 461 at a depth of about 40 feet, another high resistivity/likely impermeable contact is evident in the data; however, this feature is not well resolved, as the data begin to taper off at depth in this area of the profile.

Groundwater

The depth to groundwater along Line 1 was interpreted based on resistivity data correlations with ties to known groundwater depths in the Malaga Plaza area (provided by Geosyntec), as well as field observations of water in manholes and catch basins during the resistivity survey. Based on these correlations, the depth to groundwater beneath the area of the fault block (and extending northwest of it) is indicated with a dashed pink line in Figure 2. It should be understood that the groundwater contact shown is *approximate only* and is based on a sharp drop vertical drop in resistivity and the assumption that groundwater is conductive, with a resistivity value ranging between 0.1 and about 3 Ohm-meters (darkest to deep blue colors). In addition, while groundwater may actually undulate or exist in pockets, the groundwater contact has been smoothed and generalized along the contact shown. Based on these interpretations, the depth to groundwater (perched groundwater) appears to range between 2 feet and 13 feet bgs beneath the area of the fault block and drops to between 12 and 15 feet bgs northwest of about Station 450. The thickness of this saturated perched zone above the Valmonte, based on the data, ranges between about 13 and 41 feet, but generally is about 25 to 35 feet thick beneath the area of the fault block. A summary of groundwater depths/elevations and key contacts in the area of the fault block along Line 1 is provided in Table I.

It should be mentioned that, beginning at about MSL 130 or so (100 to 110 feet bgs) between Stations 285 and 382, a layer of low to very low resistivity (between 3 and about 0.7 Ohm-meters) beneath the Valmonte is evident in the data. Apparent continuity between this zone and the vertical/subvertical zones of conductive water either side of the fault block suggests a possible zone of confined conductive groundwater at this depth in the area of the fault block. Because this apparent conductive zone occurs at the maximum depth of detection along Line 1 it is not well defined.

Line 2

The resistivity profile for Line 2 is presented in Figure 3. As in Figure 2, the numbers on the horizontal axis represent ground distance (Station) in feet along the line, and the numbers on the vertical axis are MSL elevations in feet. As previously mentioned, the data collected along Line 2 were noisier/of slightly lower quality than that of Line 1. This likely was because of the presence of numerous metallic/conductive utilities along Line 2 and, in particular, steel or steel reinforced storm drain lines, storm drain vaults, and steel water lines. The effect of these features was to give rise to noisy/erroneous data points at depth and at the northeast end of Line 2. The ultimate result was a slightly limited depth of investigation (about 120 feet) and a shortened length of profile for Line 2 (usable data were only available between Stations 0 and 678). Key surface features and tie points (such as the Via Chico right of way and the Geosyntec well ties), along with key interpreted geologic and hydrogeologic units, have been labeled on the profile in Figure 3.

Fault Block

The southern/southwestern boundary of the Main Fault is indicated with a heavy dashed black line in Figure 3, and corresponds approximately with Station 420 on Line 2. Northeast of Station 420 the Valmonte Diatomite unit contact (interpreted based on a roughly 73- foot thick high resistivity anomaly with resistivity values ranging from 300 to

3,000 Ohm-meters) occurs at about 69 feet bgs (MSL 171), where it appears to rise about 20 feet in elevation by time it is beneath Via Chico (about Station 480). Directly south of Station 420 a 40-foot wide vertical/subvertical zone of fractured saturated rock is evident, at least between Stations 380 and 420, based on a vertical/subvertical zone of very low to low resistivity values (ranging from 0.1 to 3 Ohm-meters – darkest blue to deep blue) that appears to extend from depth. Based on similar resistivity values and character, this feature is interpreted as the area bordering the main fault where conductive water appears to be rising vertically through a zone of fractured rock. Southwest of this fractured zone a lower layer of the Altimira Shale may be present at a depth of about 68 feet bgs, based on a layer of laterally continuous somewhat moderate resistivity values (12 to 20 Ohm-meters – green to yellow colors). The northeastern boundary of the fault block appears as a drop in resistivity at about Station 620 at a depth of about 65 feet bgs (MSL 178), where there is a suggestion of the vertical/subvertical low resistivity feature that is likely associated with water saturated fractured rock; however, this feature is not as well resolved in the data as this is in the area where the data taper off with depth.

Here it is important to note that this interpreted fault/fault block is likely what is referred to as a transpressional feature, which means that the fault likely not only has vertical offset, but also right lateral offset associated with strike-slip motion. This means that subsurface geologic contacts are likely offset not only in a north/south sense but in a WNW/ESE sense, which makes correlation of units across the fault more complex than for a simple fault with one sense of motion. At any rate, the trend of the Main Fault was interpreted by "connecting the dots" between the location of the Main Fault on Line 1 and the Main Fault on Line 2, as indicated by the resistivity data. Similarly, the locations of the vertical/subvertical zone of migrating conductive water that borders the fault block to the south and north on Line 1 were connected to the locations of this feature either side of the fault block on Line 2. The resultant trend of the interpreted fault block is indicated in Figure 1 with black striped hatching, with the apparently vertically migrating fractured water zone bordering the fault block indicated on both sides with blue triangle hatching. It also should be mentioned that, along the southern boundary of the fault block, the vertically migrating zone of conductive water-filled fractured rock appears to narrow to the southeast – where it thins from about 30 feet wide where it projects on Line 2 to just 12 feet wide where it projects on the south end of Line 1. The narrowing of this apparently conductive water-filled zone may indicate a "pinch point"-where this rising water is under greater pressure north of Station 248 on Line 1.

Groundwater

The depth to groundwater along Line 2 was interpreted based on resistivity data correlations with ties to known groundwater depths in wells PVE-4 and VC-1, as well as field observations of water in manholes and catch basins during the resistivity survey. Based on these correlations, the depth to groundwater between VC-1 and the north end of the fault block is indicated with a dashed pink line in Figure 3. It should be understood that the groundwater contact shown is *approximate only,* and in the area between Stations 420 and 590 (where there was extensive utility interference in the data) the groundwater contact is interpolated and smoothed between "clean" data points - where low resistivity values (darkest blue to deep blue) are evident in the data. This is because utility interference effects typically show up in the model section as locations of higher than expected resistivity values; an example of this is an area with a likely high resistivity artifact caused by a metallic storm drain vault and reinforced concrete storm drain between Stations 535 and 570. This feature is labeled in Figure 3.

Based on these interpretations, the depth to groundwater (perched groundwater) appears to range between 2.5 feet and about 12 feet bgs between Stations 370 and about 590, and drops to between 22 and 28 feet bgs between Stations 600 and 620. The thickness of this saturated perched zone above the Valmonte, based on the data, ranges between about 38 and 66 feet beneath the area of the fault block. A grid has been superimposed on the profile in Line 2 to clarify elevations of key features, and a summary of groundwater depths/elevations and key contacts in the area of the fault block along Line 2 is provided in Table II.

One additional feature to mention along Line 2 is an area of possible upwelling of conductive groundwater southwest of the interpreted fault block – which occurs at least between Stations 250 and about 300. This area is evident based on a roughly 15-foot thick layer of very low resistivity values (0.3 to 2 Ohm-meters-darkest blue) draped over a vertically oriented highly resistive (dark red) feature whose top appears to be about 35 feet bgs at about Station 275. Based on a tie with groundwater in monitoring well VC-1, this layer of low resistivity could correspond to conductive groundwater upwelling around a resistive/impermeable nodule of material; however, because a metallic storm drain lateral may be present in this same area (based on a map provided by the City) at least part of this anomaly could be associated with metallic interference in the data. This feature is labeled in Figure 3. Regardless, the apparent (perched) groundwater contact is identified with a dashed pink line in this area and ranges between 10 feet (high point at Station 275) and 32 feet bgs between Station 250 and 300.

Southwest of this feature (between Stations 0 and at least 240) the near surface data display the type of variable resistivity values typically seen in alluvium; based on this and review of the geologic maps for the Property, this alluvium may be associated with terrace deposits. With this assumption, the base of the terrace deposits is indicated with a dashed brown line in Figure 3, where the low resistivity values beneath the terrace deposits suggest that either fractured shale or conductive water-filled fractured shale lies beneath the terrace deposits.

LIMITATIONS

It should be understood that the geologic interpretations made during this investigation (and geologic units labeled in Figures 2 and 3) were made based almost entirely on resistivity data values, experience and assumptions from previously mapped units indicated in the geologic maps (Dibblee and Cleveland geology) for the area. No direct observation or verification of the depth to the Valmonte Diatomite or the Altimira Shale was made or available during this survey, and Spectrum provides no warranty (either express or implied) that these specific geologic units and/or precise contacts of the Monterey Formation are present at the depths and elevations indicated in the profiles or in Tables I and II, or as discussed in this report.

In addition, it should be mentioned that a significant amount of utilities is present along Via Campesina and in the intersection of Via Campesina and Via Chico. These utilities are not shown in Figure 1; however, Spectrum recommends that Geosyntec or the City call 811 or hire a utility locating firm before breaking ground or drilling in the area investigated.

We appreciate the opportunity to provide these results to Geosyntec.
Please let us know if there are any questions regarding this summary report.

Sincerely,

SPECTRUM GEOPHYSICS

Laura Cathcart-Dodge

LAURA L. CATHCART-DODGE
No. 1017
Exp. 12/25

Laura Cathcart-Dodge, P.GP.
Vice President/Principal
California Professional Geophysicist# 1017

Attached Figures and Tables:

REFERENCES

Conrad, C.L. and Ehlig, P.L., 1987, The Monterey Formation of the Palos Verdes Peninsula, California - An example of sedimentation in a tectonically active basin within the California continental borderland: *in* Fischer, F.J. (ed.), Geology of the Palos Verdes Peninsula and San Pedro Bay: Pacific Section of the Society of Economic Paleontologists and Mineralogists, Guidebook 55, p. 17-30.

Dibblee, Jr., T. W., 1999, Geologic map of the Palos Verdes Peninsula and vicinity, Redondo Beach, Torrance, and San Pedro quadrangles, Los Angeles county, California: Dibblee Foundation Geological Map DF-70, scale 1:24,000.

METHODS

Electrical Resistivity Method

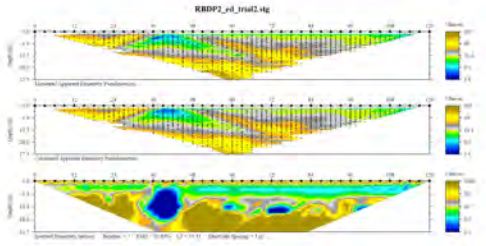
DC resistivity data provide high quality, high resolution imaging of subsurface layers where there is a contrast in electrical resistivity across a geologic contact. Examples of materials with contrasting resistivity are: permeable sand vs. impermeable shale, fresh-water coarse sands and cobbles vs. clays, high TDS water vs. fresh water, and highly fractured/sheared rock vs. unweathered/unsheared rock. The electrical resistivity method had its beginnings in the mining industry but is now commonly used in the environmental and engineering businesses. The electrical resistivity of a material is a measure of the ease with which an electrical current can flow through that material. In the electrical resistivity method, a DC circuit is established in the ground via cables and electrodes, and the ground acts as the resistor to complete the circuit. There are several different geometrical arrays that can be used to collect the data; however, the most common are Wenner, Schlumberger and dipole-dipole. Electrical resistivity data are typically displayed in 2D sections or profiles where they supply lateral and vertical electrical resistivity information about materials directly below a given transect (much like a road cut).

SuperSting Electrical Resistivity System

A useful property of electrical resistivity for dry sedimentary soils and rocks is that an increase in grain size generally causes an increase in resistivity (e.g., coarse-grained materials such as gravel or cobbles have higher resistivity values than finer grained materials such as fine sands and silts). Because the electrical resistivity of a material correlates well with grain size, this method can be used not only to identify lateral and vertical boundaries between different units but also to identify the lithology of the material (e.g., sand vs. silt vs. clay). As electrical current flow through sedimentary soils and rocks is primarily electrolytic, permeable materials (such as coarse sands or sandstones) are less resistive (or more conductive) when fully saturated than when dry – which makes the electrical resistivity method useful for many groundwater applications. In addition, electrical resistivity data can be used to delineate areas with saline or high TDS groundwater saturation, as these areas typically exhibit low resistivity values.

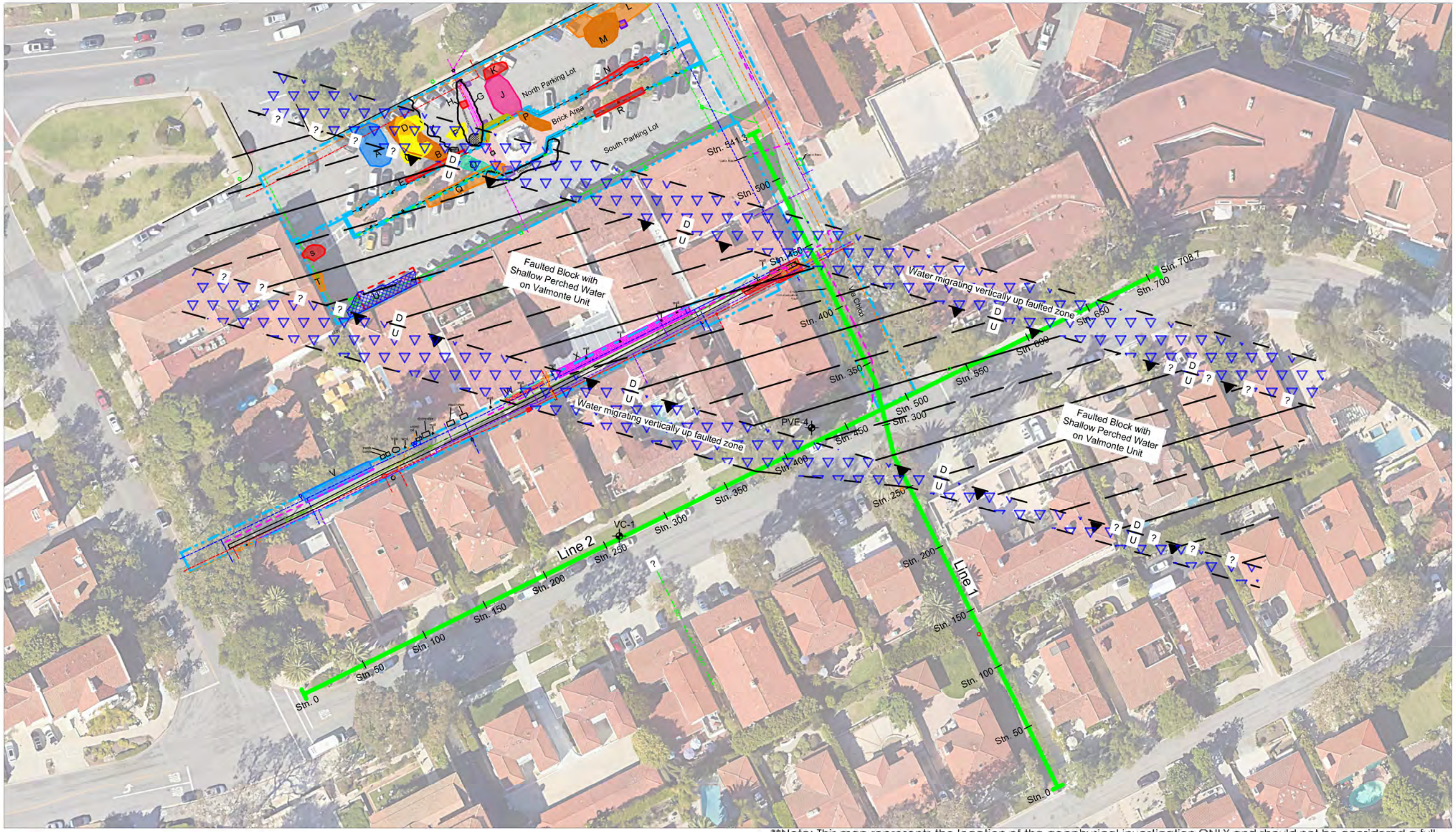
The SuperSting is a system that allows automated acquisition of electrical resistivity data. Because it is automated it is quite efficient and relatively easy to use in the field. During a resistivity survey, a known amount of current is introduced into the ground through two electrodes. This current then travels through the ground and the electrical potential is measured by 2 other electrodes some distance from the current electrodes. Ohm's Law (V=IR) is then used to calculate the apparent resistivity of the ground through which the current has traveled. During a SuperSting survey, many apparent resistivity measurements are made for a suite of electrode pair separations, and these apparent resistivity values are plotted on a two-dimensional diagram (location of measurement vs. depth). The result is a 2D subsurface image that contains both sounding and profiling data. The automated resistivity data acquisition provided by the SuperSting allows for a tremendous amount of data to be acquired relatively quickly at very high-resolution capability. Once the data have been acquired for a given transect, they can be downloaded to a field computer and subsequently viewed, color-contoured, and processed to generate a model resistivity section, as described below.

During this survey, the data file saved for each transect is entered into the software program EarthImager® (AGI, 2015). This program reads the data file, which contains information such as electrode spacing, length of transect, number of repeat measurements per electrode, type of resistivity array, and topography. Once the raw data are read into EarthImager® the data are reviewed for indications of erroneous or noisy data. This is a “hands on” detailed process where noisy data points are deleted, the new, edited file is saved, and the process repeated until an acceptable noise level in the data is reached (generally in the 1% to 3% range). Once noise levels are acceptable, inversion of the data begins. First, the data are sorted into finite element blocks and each block is assigned an initial resistivity value. A forward modeling algorithm that uses a non-linear least squares optimization technique is then used to calculate apparent resistivity values that would be measured with the given array type for the starting model. The *calculated* apparent resistivity values are then compared with the *measured* apparent resistivity values, and the difference between the two used to adjust the model block values to produce a model that has a lower root-mean-square (RMS) error fit to the measured section. The program advances through a series of iterations until an acceptable error level is reached (usually 10% or less) or the model fails to improve.



Electrical Resistivity Pseudosections and Model Section

The final product of EarthImager® processing is a color-contoured *model section* for the line of data acquired, where different colors are assigned to different values of resistivity. It should be noted that the resolution of the resistivity method decreases with increasing depth. Therefore, the finite element mesh becomes coarser with depth, providing lower resolution and a more generalized model. This tends to produce broadening and flattening along the lower boundary. The highest resolution and most accurate depth conversion data are provided in the upper 30% of the model section, where the overall resolution is approximately one-half the unit electrode separation (in this case, 1 meter). It is from this model section that interpretations of lithologic contacts such as shales vs sands, hydrogeologic units such as permeable and confining layers, as well as geologic contacts/structural features, is made.



—	Resistivity Transect
D ▼ U ▼ ▼ ▼	Reverse Fault, teeth on upthrown side, queried where uncertain
— — SD? —	Storm Drain, approximate location provided by City map
⌖	Geosyntec Well
○	Storm Drain Manhole
○	Telecommunication Manhole
○	Electric Manhole

N
W E
S
North

Scale: (Feet)
0 20 40 80

**Note: This map represents the location of the geophysical investigation ONLY and should not be considered a full site survey including utilities.

**Note: This map does not show utilities on Via Campesina

***Note: Not all below ground utilities or features may be represented on this map

811
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MAP
Geophysical Interpretation Map with Phase 1 GPR

PROJECT
Malaga Cove Plaza
36 Malaga Cove Plaza
Palos Verdes, California

PREPARED FOR
Geosyntec Consultants, Inc.
Los Angeles, California

FIGURE NO.
1

PROJECT NO.
8901

SCALE
1 inch = 80 feet

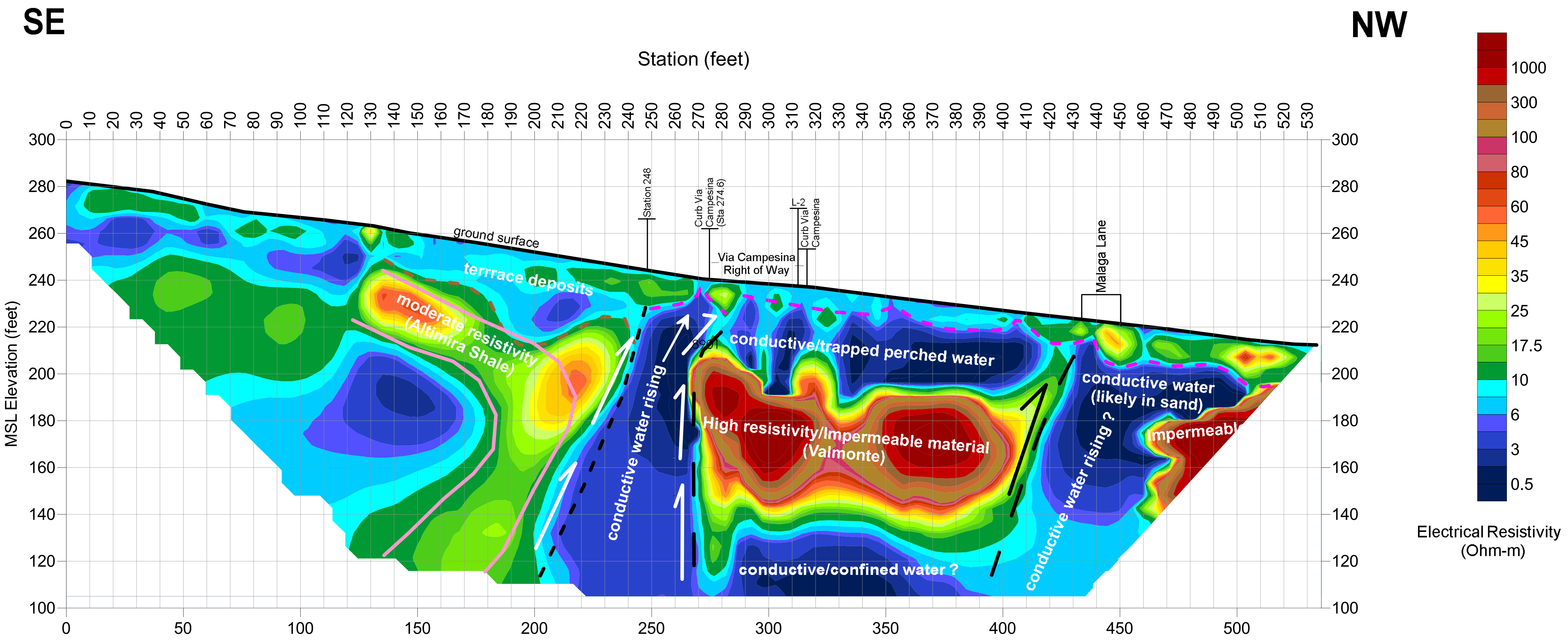
FIGURE BY
CDE

REVIEWED BY
LCD

DATE
6/4/2024

LINE 1 - B TO B'

Electrical Resistivity Profile



Top of water bearing zone (interpreted)

Geologic Fault - Arrow indicates sense of movement (interpreted)

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MAP
Electrical Resistivity Profile - Line 1

FIGURE NO.
2

PROJECT
Geophysical Investigation
Malaga Cove Plaza
Palos Verdes Estates, California

PREPARED FOR
Geosyntec

PROJECT NO.
8901

SCALE
1 inch = 50 feet

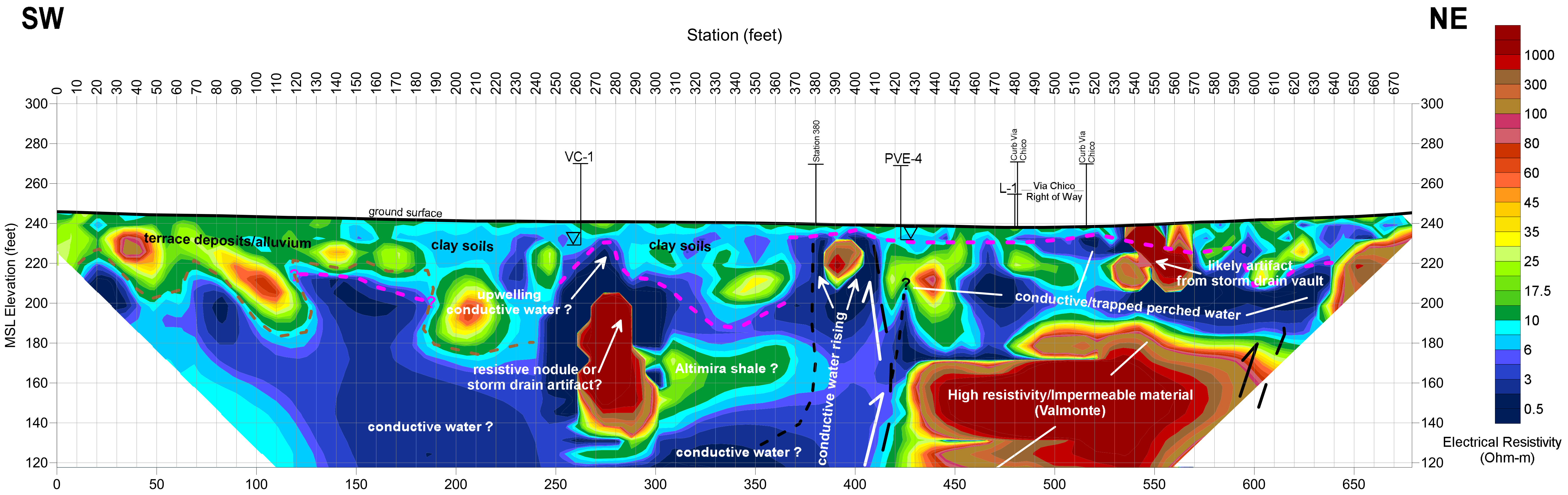
FIGURE BY
BAU

REVIEWED BY
LCD

DATE
6/4/24

LINE 2 - A TO A'

Electrical Resistivity Profile



∇ **Approx. level of groundwater on 1/9/2024 (provided by Geosyntec)**

Top of water bearing zone (interpreted)

Base of terrace deposits (interpreted)

Geologic Fault - Arrow indicates sense of movement (interpreted)

spectrum geophysics REVEALING THE SUBSURFACE	MAP **Electrical Resistivity Profile - Line 2**	FIGURE NO. **3**
	PROJECT Geophysical Investigation Malaga Cove Plaza Palos Verdes Estates, California	
16691 GOTHARD, SUITE L HUNTINGTON BEACH, CA 92646 (818) 886-4500 www.spectrum-geophysics.com	PREPARED FOR Geosyntec	PROJECT NO. 8901
	SCALE 1 inch = 50 feet · FIGURE BY BAU · REVIEWED BY LCD	DATE 6/2/24

TABLE I: Groundwater Elevations, Line 1 Resistivity, Malaga Cove Plaza

Line 1 Station (ft)	Surface Elev (MSL-ft)	Top of Water Elev (MSL ft)	Bottom of Water/top of Valmonte (MSL-ft)	Depth to Water (ft)	Thickness of Water Zone (ft)	Depth to Valmonte (ft)
240	245.2	197.2	NA	48	Unknown	NA
250	244.2	225.5	NA	18.7	Unknown	NA
260	242.7	230	NA	12.7	Unknown	NA
270	240.9	236.4	209	4.5	27.4	31.9
280	240	226.8	214.2	13.2	12.6	25.8
290	239.5	233.4	203.6	6.1	29.8	35.9
300	238.9	231.9	190.5	7	41.4	48.4
310	238.5	229.9	190.5	8.6	39.4	48
320	237.5	228.4	209.1	9.1	19.3	28.4
330	236	226.8	187.9	9.2	38.9	48.1
340	234.4	226.3	190.9	8.1	35.4	43.5
352	233.4	231.4	195.5	2	35.9	37.9
360	232.4	225.3	194	7.1	31.3	38.4
370	230.9	221.3	194.5	9.6	26.8	36.4
380	229.4	219.3	194.5	10.1	24.8	34.9
390	228.4	219.3	193	9.1	26.3	35.4
400	227.4	218.8	191.5	8.6	27.3	35.9
406	226.4	223.3	193.5	3.1	29.8	32.9
410	225.8	218.7	195.5	7.1	23.2	30.3
420	224.8	214	205	10.8	9	19.8
430	223.8	213.7	NA	10.1	Unknown	NA
440	222.8	213.2	NA	9.6	Unknown	NA
450	221.8	203.6	NA	18.2	Unknown	NA
460	220.8	205.1	146	15.7	59.1	74.8
470	219.3	204.1	181.9	15.2	22.2	37.4
480	218.3	203.6	179.9	14.7	23.7	38.4
490	216.7	204.6	185.4	12.1	19.2	31.3
500	215.7	198	186.9	17.7	11.1	28.8
505	214.7	195.5	190.9	19.2	4.6	23.8

TABLE II: Groundwater Elevations, Line 2 Resistivity, Malaga Cove Plaza

Line 2 Station (ft)	Surface Elev (MSL-ft)	Top of Water Elev (MSL ft)	Bottom of Water/top of Impermeable unit (MSL-ft)	Depth to Water (ft)	Thickness of Water Zone (ft)	Depth to Impermeable or Valmonte (ft)	Comments
250	240.6	207.2	NA	33.4	Unknown	NA	Upwelling around SD lateral/resistive nodule?
260	240.6	217.3	NA	23.3	Unknown	NA	Upwelling around SD lateral/resistive nodule?
270	240.6	225.9	201.7	14.7	24.2	38.9	Upwelling around SD lateral/resistive nodule?
280	240.6	218.7	205.7	21.9	13	34.9	Upwelling around SD lateral/resistive nodule?
290	240.6	210.8	175.9	29.8	34.9	64.7	Upwelling around SD lateral/resistive nodule?
300	240.6	208.8	174.4	31.8	34.4	66.2	Upwelling around SD lateral/resistive nodule?
310	240.6	202.7	NA	37.9	Unknown	NA	
320	240.6	195.1	NA	45.5	Unknown	NA	
330	240.6	187	NA	53.6	Unknown	NA	
340	240	186.5	NA	53.5	Unknown	NA	
350	240	191.6	NA	48.4	Unknown	NA	
360	240	196.1	NA	43.9	Unknown	NA	
370	239.6	232.5	NA	7.1	Unknown	NA	Fault Zone/rising water
380	239.6	233.5	NA	6.1	Unknown	NA	Fault Zone/rising water
390	239.6	234.5	NA	5.1	Unknown	NA	Fault Zone/rising water
400	239	236.5	NA	2.5	Unknown	NA	Fault Zone/rising water
410	239	233.5	NA	5.5	Unknown	NA	Fault Zone/rising water
420	239	231.5	NA	7.5	Unknown	NA	Fault Zone/rising water
425	238.6	230.5	164.3	8.1	66.2	74.3	Valmonte Present
430	238.6	230.5	168.3	8.1	62.2	70.3	Valmonte Present
440	238.6	230.5	171.4	8.1	59.1	67.2	Valmonte Present
450	238.6	231	171.4	7.6	59.6	67.2	Valmonte Present
460	238.6	230.5	170.9	8.1	59.6	67.7	Valmonte Present
470	238	230.5	171.4	7.5	59.1	66.6	Valmonte Present
480	238	230.5	171.4	7.5	59.1	66.6	Valmonte Present
490	238	230.5	184	7.5	46.5	54	Valmonte Present
500	238.2	231.5	189.6	6.7	41.9	48.6	Valmonte Present
510	238.2	232.5	189.6	5.7	42.9	48.6	Valmonte Present
520	238.6	234	189.1	4.6	44.9	49.5	Valmonte Present
530	238.7	232.5	189.1	6.2	43.4	49.6	Valmonte Present
540	239	233.6	189.7	5.4	43.9	49.3	Valmonte Present
550	239.7	232.1	184.1	7.6	48	55.6	Valmonte Present
560	240.1	230.6	181.6	9.5	49	58.5	Valmonte Present
570	240.7	229.1	180.1	11.6	49	60.6	Valmonte Present
580	241.1	230.6	178.6	10.5	52	62.5	Valmonte Present
590	241.2	232.1	177.6	9.1	54.5	63.6	Valmonte Present
600	241.7	212.9	174.5	28.8	38.4	67.2	Valmonte Present
610	242.2	213.9	168.5	28.3	45.4	73.7	Valmonte Present
620	242.7	220.5	162.9	22.2	57.6	79.8	Valmonte Present
630	242.7	223	160	19.7	63	82.7	Valmonte Present