Refraction Seismic Investigation
at the
Ascenté Development Site,
Reno, Washoe County, Nevada

GGSI Project No. 2017-29.01

Prepared by:

Gasch Geophysical Services, Inc.
Rancho Cordova, California 95742-6576

Submitted to:

Mr. Mitch Burns
Lumos & Associates, Inc.
800 College Parkway
Carson City, Nevada 89701

October, 2017

GASCH GEOPHYSICAL SERVICES, INC.
WWW.GEOGASCH.COM Since 1969

October 9, 2017

Mr. Mitch Burns
Lumos & Associates, Inc.
800 College Parkway
Carson City, Nevada 89701

Re: Refraction Seismic Investigation at the Ascenté Development Site in Reno, Washoe County, Nevada.
GGSI Project No. 2017-29.01

Dear Mr. Burns,

At your request and authorization, Gasch Geophysical Services, Inc. (GGSI) has completed a refraction seismic investigation to evaluate the characteristics of the sub-surface materials and locate suspected faults at the Ascenté Development Site in Reno, Washoe County, Nevada (Figure 1).

Purpose

The purpose of this investigation was to define the characteristics of the sub-surface and the depth to higher velocity material to aid in determining the excavatability of materials in areas of proposed roadway and housing pad cuts. Additionally, refraction seismic data were used to aid in determining the existence and/or extent of several fault systems thought to be present in the area.

Method, Instrumentation and Software

The refraction seismic (RS) method was used to evaluate the rock velocities on site, as seismic primary-wave travel times are used to quantify the rock velocities and, as a result, can determine the general competency/rippability in areas of various rock types. The RS method measures the velocity at which a seismic wave propagates through a soil or rock medium. In this case, the primary seismic wave (p-wave) was measured. Higher seismic p-wave velocities (measured in feet per second, ft/s) indicate material of higher density, thus quantifying the competency, or strength, of the soil or rock medium and providing an estimation of the rippability and/or excavatability of the sub-surface materials.

GGSI's seismic data acquisition system was a Seistronix EX-6 Explorer which is a distributed, 24-bit digital instrument with data output to electronic media for subsequent processing. Geophones were single, 28-Hz, digital grade units manufactured by OYO Geospace Corporation. Spread cables were manufactured by Pro-Seismic Services. The energy source for this project was a sixteen pound sledge hammer with a hardwired link for system triggering. All data were processed in house, on our data reduction and plotting workstation.

Refraction seismic data processing was carried out using Rayfract® version 3.34. This refraction seismic processing software utilizes Wavepath Eikonal Traveltime (WET) tomography, which models multiple signal propagation paths contributing to one first break (the Fresnel volume approach). Conventional ray tracing tomography is limited to the modeling of just one ray path per first break. The WET inversion method is founded upon a back-projection formula for inverting velocities from travel times computed by a finite-difference solution to the Eikonal equation (Qin, et al. 1992). An Eikonal solver is used for traveltime field computation which models diffraction in addition to refraction and transmission of acoustic waves. As a result, the velocity anomaly imaging capability is enhanced with the WET tomographic inversion method compared to conventional ray tomography. This software is developed by Intelligent Resources, Inc. of Vancouver, British Colombia, Canada.

A color-coded seismic velocity cross-section of the subsurface has been generated for each RS line, where cool colors (blues) indicate lower seismic velocities and warm colors (reds, purple) indicate higher velocities. Color scaling of these seismic velocity sections is based on the range of seismic velocity values calculated. Velocity scaling has been normalized on all RS velocity sections.

Data Acquisition Parameters

A total of 7 RS lines were acquired during this investigation. RS Line locations were suggested by Lumos personnel and slightly adjusted in the field to allow for efficient and safe data acquisition. The end points of each line were marked in the field using orange stakes with appropriate labels and pink flagging material. All seven lines were acquired with geophone stations spaced at 20-foot intervals. RS Lines 1, 2, 3, 5, and 7 were acquired with 24 geophone stations for total line lengths of 500 feet each. RS Line 4 was acquired with 39 geophone stations for a total line length of 800 feet, and RS Line 6 was acquired with 12 geophone stations for a total line length of 260 feet. Energy source points were located every other geophone station, as well as off the ends of each line. A total of 3,560 lineal feet of data were collected for all 7 lines. Collection of the field data were carried out on October 2nd and 3rd, 2017. The field crew consisted of Professional Geophysicist Kent Gasch and Geophysicist Tim Brandt. The locations of the RS lines are presented on Figure 2.

Rippability

Rippability is dependent on the physical condition of the rock masses to be excavated. In addition to rock type and degree of weathering, structural features in the rock such as bedding planes, cleavage planes, joints, fractures, consolidation and shear zones also influence rippability. Rock masses tend to be more easily ripped if they have well defined, closely spaced fractures, joints, or other planes of weakness. Massive rock bodies which lack discontinuities may allow for slow and difficult ripping or refusal, even where partially weathered, and may require blasting to break the rock for efficient removal.

The association between the seismic velocity of any given earth material and its rippability varies greatly from one type of earth-moving equipment to another. For example, although a large track laying dozer with a single ripper tooth can sometimes rip material with seismic velocities in excess of 10,000 ft/s, GGSI has experienced a limiting (refusal) velocity for large excavators to range from 3,500 ft/s to 4,500 ft/s, and a standard backhoe may meet refusal at seismic velocities as low as 2,000 ft/s. Although low seismic velocities in any rock type indicate probable rippability, if the fractures, bedding and/or joints do not allow tooth penetration, the material still may not be ripped efficiently. In some cases, drilling and blasting may be required to induce sufficient fracturing to allow for excavation. Ultimately, the relationship between seismic velocity and rippability is dependent on a combination of site conditions, equipment and/or operator ability.

Seismic p-wave velocities are related to both rock hardness and fracture density. Rippability has been empirically correlated to refraction seismic velocities by Caterpillar Inc., as displayed on Figure 10 for a CAT D10R (Caterpillar Performance Handbook, Edition 45, January, 2015). According to this chart, igneous rock, in this case rhyolite becomes marginally rippable near 7,200 ft/s and non-rippable at around 8,500 ft/s for a D10R dozer with a single shank ripper tooth. These estimations are based on the published values for metamorphic rocks on the CAT chart; however, site geology and topography may cause some variations of these values.

The Caterpillar Chart of Ripper Performance should be considered as being only one indicator of rippability. Ripper tooth penetration is the key to successful ripping, regardless of seismic velocity. This criterion is particularly true in finer-grained, homogeneous materials and in tightly cemented formations. Ripping success may ultimately be determined by the operator finding the proper combination of factors, such as: number of shanks used, length and depth of shank, tooth angle, direction of travel, and use of throttle. Although low seismic velocities in any rock type indicate probable rippability, it is possible that, if the fractures, bedding and/or joints do not allow tooth penetration, the material still may not be ripped efficiently. In some cases, drilling and blasting may be required to induce sufficient fracturing to allow for excavation.

Seismic Velocities

Generally, seismic p-wave velocities less than 3,000 ft/s indicate native soil, fill material or highly weathered and/or decomposed rock, while velocities in excess of 10,000 ft/s indicate fresh (essentially non-weathered) rock. Seismic velocities between these two values typically indicate rock with varying degrees of weathering and/or fracturing. Consolidation and cementation, as well as, fracture spacing and density also affect the measured seismic velocities. Moderate velocities may indicate compacted soil, moderately weathered rock or loosely consolidated sediment such as gravel, sand and silt. Saturated sediment below the water table characteristically displays seismic velocities near or slightly above 5,000 ft/s.

Extremes in seismic velocities may range from below 1,000 ft/s to over 20,000 ft/s. Very low seismic velocities usually indicate highly weathered or poorly compacted material, either natural or man-made. Extremely high velocities are rare in the near-surface, and only possible in certain types of rock. Rock velocities are dependent on the physical condition of the rock masses evaluated, as a result, seismic p-wave velocities are related to rock hardness, fracture density and sediment consolidation, saturation and cementation.

Findings

The results of this refraction seismic investigation are summarized by Figures 3 through 9. These seismic velocity sections, which were created through the inversion process, have very low error and provide a high degree of lateral definition of the seismic velocity horizons found beneath each line. The seismic velocity sections have been scaled from 1,500 ft/s to 20,000 ft/s for the velocity window. Horizontal and vertical axes have both been scaled to 40 feet per inch on all RS lines except for RS Line 4, which was scaled to 60 feet per inch in both the horizontal and vertical axes. In addition, the approximate coordinates of each endpoint, as acquired in the field using a handheld Garmin GPSmap 76CSx, have been labeled on each figure.

RS Line 1 (Figure 3)

RS Line 1 is located in the central-western portion of the project area. This Line is oriented approximately southwest to northeast (see Figure 2) and is positioned approximately 4 feet west of Lumos Stake No. 1017 at geophone station 112+00 feet.

Measured seismic velocities at this location generally stay below 7,000 ft/s across the length of the line down to the maximum depth of exploration at approximately 80 feet below ground surface (bgs). Measured seismic velocities also stay below 5,000 ft/s down to apparent depths of 30-40 feet bgs on the entire line. Based on information provided by Lumos personnel, the maximum planned cut depth in this area is approximately 20-25 feet bgs. Measured velocities in this depth range are 5,000 ft/s or less across all of RS Line 1, suggesting that materials in this area should be rippable with a large dozer down to the proposed maximum cut depth.

RS Line 2 (Figure 4)

RS Line 2 is located in the central portion of the project area. This Line is oriented approximately west to east (see Figure 2) and is positioned approximately 15 feet north of Lumos Stake No. 1019 at geophone station 215+00 feet.

Measured seismic velocities at this location also generally stay below 7,000 ft/s across the length of the line down to the maximum depth of exploration at approximately 105 bgs. Measured seismic velocities also stay below 5,000 ft/s down to apparent depths of 25-95 feet bgs on the entire line. Based on information provided by Lumos personnel, the maximum proposed cut depth in this area is approximately 15-20 feet bgs. Since measured velocities in this depth range are 5,000 ft/s or less across the line, it suggests that materials in this area should be rippable with a large dozer down to the proposed maximum cut depth.

RS Line 3 (Figure 5)

RS Line 3 is located in the central-eastern portion of the project area. This Line is oriented approximately southeast to northwest (see Figure 2) and is positioned approximately 5 feet west of Lumos Stake No. 1021 at geophone station 302+3 feet.

Measured seismic velocities at this location grade at a rapid rate on the southeast end of the line and very gradually on the northwest end. The southeastern end of the line shows a rapid gradation from the from distance station -20 feet to 100 feet where velocities range from less than 5,000 ft/s at the surface to over 11,000 ft/s at the maximum depth of exploration at the extreme southeast end of the line. On the northwestern end of the line, low to moderate velocities were measured from distance station 100 feet to the end of the line. Velocities grade most rapidly from the southeast end of the line to distance station 100 feet, at which point there is an abrupt shift to lower velocity material down to the maximum depth of exploration (~80 feet bgs) for the remainder of the line. Based on information provided by Lumos personnel, the maximum proposed cut depth in this area is approximately 20-25 feet bgs. Measured velocities at this depth are near 9,000 ft/s from distance station -20 feet to 60 feet indicating non-rippable material in this area. From distance station 60 feet to approximately 75 feet, velocities suggest marginally rippable material and rippable material from distance stations 75 feet to the northwest end of the line. Between distance stations -20 feet to 60 feet, where velocities are greater than 7,200 ft/s, excavation progress is likely to slow and drilling and blasting may be the most efficient method to fracture the rock for further excavation.

RS Line 4 (Figure 6)

RS Line 4 is located in the northwest corner of the project area. This Line is oriented approximately northwest to southeast (see Figure 2). Based on information provided by Lumos personnel, RS Line 4 is located in an area where minimal cutting is to occur. The main purpose of this line was to evaluate the existence of a fault trace previously mapped in this area.

The seismic data show a distinct set of abrupt shifts at depth, indicative of faulted and/or displaced strata, ranging from distance station 580 feet to distance station 750 feet at the surface. The data show this possible fault zone dipping to the northwest at approximately a 45º angle to the maximum depth of exploration of approximately 285 feet bgs. The location of this possible fault zone, which has been labeled on the figure for ease of viewing, corresponds well to the location of the fault trace previously mapped to the area.

RS Line 5 (Figure 7)

RS Line 5 is located in the southwest corner of the project area. This Line is oriented approximately east to west (see Figure 2) and is positioned approximately 30 feet south of Lumos Stake No. 1045 at geophone station 516+00 feet. The purpose of this line was to provide excavatability characteristics and to evaluate the previously located fault trace found during trenching work.

Measured seismic velocities at this location grade slowly, generally less than 7,000 ft/s across the length of the line down to apparent depths ranging from 40 feet to 100 feet bgs. Based on information provided by Lumos personnel, the maximum proposed cut depths in this area range from approximately 5-15 feet bgs. Measured seismic velocities are less than 5,000 ft/s down to apparent depths of 24-50 feet bgs across the entire length of the line. Since measured velocities in this depth range are 5,000 ft/s or less across all of RS Line 5, it suggests that materials in this area should be rippable with a large dozer down to the proposed maximum cut depth.

In addition, this line sought to evaluate the existence of a fault trace previously located in this area via trenching. The seismic data show a distinct shift at depth, indicative of faulted and/or displaced strata, ranging from distance station 190 feet to distance station 270 feet at the surface. The data show this possible fault zone dipping to the east at approximately a 70-75º angle down to the maximum depth of exploration at approximately 160 feet bgs. The location of this possible fault zone, which has been labeled on the figure for ease of viewing, corresponds well to the location of the fault trace previously found in the area during trenching work.

RS Line 6 (Figure 8)

RS Line 6 is located in the northwestern portion of the project area. This Line is oriented approximately northwest to southeast (see Figure 2) and is positioned approximately 6 feet north of Lumos Stake No. 1003 at geophone station 602+00 feet.

Measured seismic velocities at this location grade moderately with a dip of higher velocities to the northwest. Based on information provided by Lumos personnel, the maximum proposed cut depths in this area range from approximately 5-10 feet bgs. Measured seismic velocities are less than 5,000 ft/s to depths of approximately 24 feet across the entire line, which suggests that materials in this area should be rippable with a large dozer to the proposed maximum cut depth.

RS Line 7 (Figure 9)

RS Line 7 is located in the southwest corner of the project area. This Line is oriented approximately south to north (see Figure 2) and is positioned approximately 11 feet east of Lumos Stake No. 1040 at geophone station 713+07 feet and is in line with Lumos Stake No. 1039 at geophone station 719+14 feet.

Based on information provided by Lumos personnel, the maximum planned cut depths in this area are approximately 5-20 feet bgs. Measured seismic velocities at this location shows moderately undulating velocity contours with low velocities at the surface and grading to high velocities at the maximum depth of exploration. At 20 feet bgs, velocities are less than 4,000 ft/s which are well within the range of rippable material at the maximum depth of planned cuts. Material in this area should be rippable with a large dozer down to the proposed maximum cut depth.

Summary

This refraction seismic investigation revealed a moderate degree of variation in the calculated seismic velocities of the subsurface materials, with maximum seismic velocity values greater than 19,000 ft/s measured on Line 4. Lower velocity material (1,500 ft/s to 3,000 ft/s) was encountered in the near surface on all lines which is suggestive of native soil, fill material or highly weathered and/or decomposed rock. All RS Lines show a moderate to high velocity section of material, to some extent, from near-surface to varying depths. The moderate to high velocities ranging from 3,000 ft/s to the 7,000+ ft/s, suggests highly compacted soil or fill and/or rock with varying degrees of fracturing, weathering which would expectedly decrease with depth and increase in velocity.

In general, rippability with a large track laying dozer should not be problematic, except where noted on RS Line 3, in the areas of this refraction seismic data based on the CAT D10R Rippability Performance Chart (Figure 10). Based on this information and cut-and-fill information provided by Lumos personnel, it is likely that excavation crews will encounter rippable materials down to the proposed maximum cut depths on all seven RS Lines, except for a short section on RS Line 3 where blasting may be necessary. It should also be noted that observed rock outcrops at the site may could be associated with large rock masses (large boulders) which may be difficult to remove mechanically and may require blasting to move efficiently.

Warranty and Limitations

Gasch Geophysical Services, Inc. has performed these services in a manner which is consistent with standards of the profession. Site conditions can cause some variations of the calculated seismic velocities. Refraction seismic velocities assume that velocities increase with depth; therefore, a lower seismic velocity layer beneath a higher seismic velocity layer will not be resolved. No guarantee, with respect to the results and performance of services or products delivered for this project, is implied or expressed by Gasch Geophysical Services, Inc.

We trust that this is the information you require; however, should you have comments or questions, please contact our Rancho Cordova office at your convenience. Thank you for this opportunity to again be of service.

Sincerely,

GASCH GEOPHYSICAL SERVICES, INC.

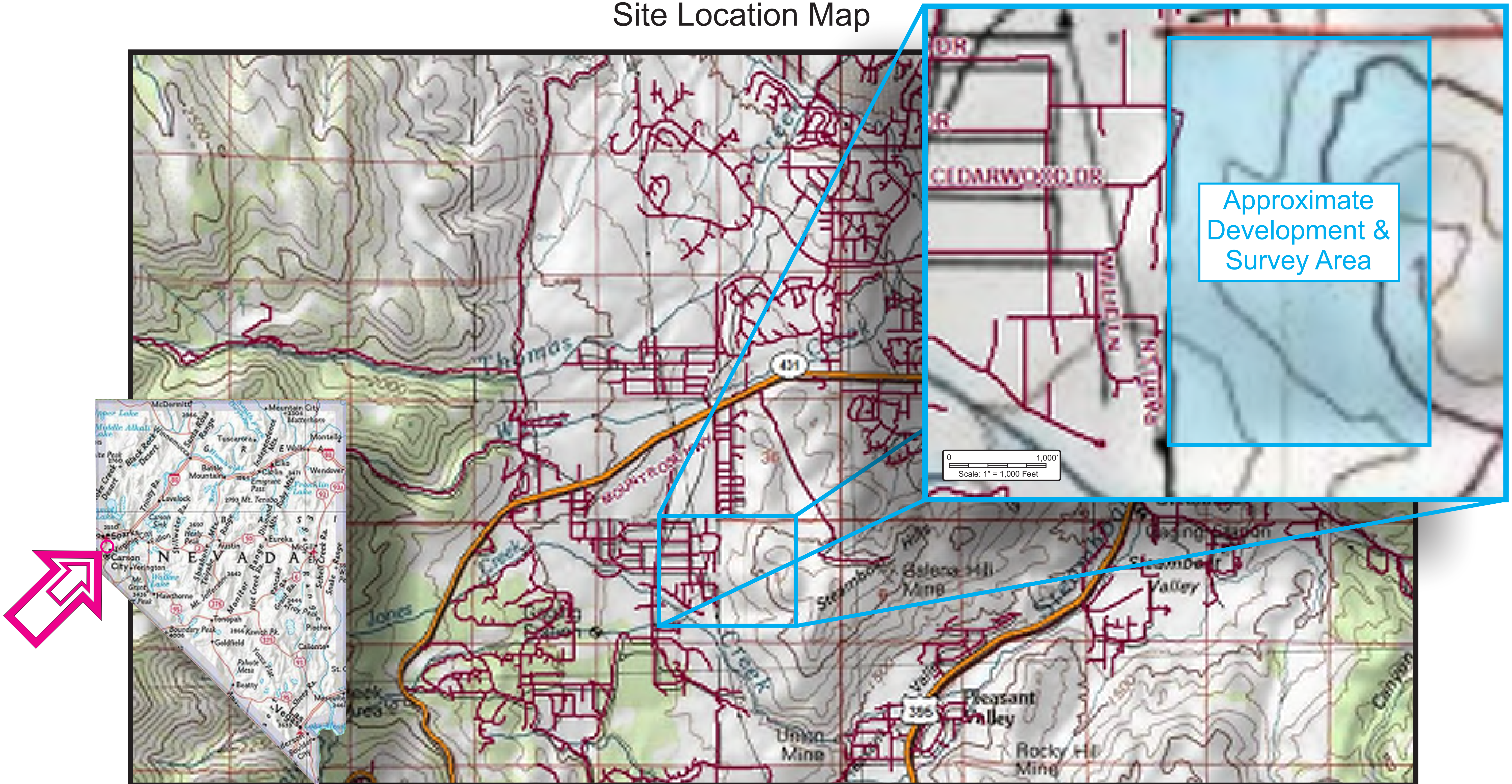
Professional Geophysicist
Kent L. Gasch
No. 1061
State of California

Expires 12/31/2017

Kent L. Gasch
Professional Geophysicist #1061

Timothy W. Brandt
Geophysicist

Site Location Map



Base Maps Courtesy of: USGS

0 0.5 1 1.5 2 miles
0 1 2 3 kilometers

North

Figure 1

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Refraction Seismic Investigation: Ascenté Development Site

Prepared for:* *Lumos & Associates

Project Number: 2017-29.01 ***Date:*** October, 2017

RS Line Location Map

Base Map Courtesy of Google Earth Pro

0' 250' 500' 1000'
Scale: 1" = 500'

North

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Figure 2

Refraction Seismic Investigation: Ascenté Development Site

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