ADDENDUM GEOTECHNICAL INVESTIGATION
GROUND MOTION HAZARD EVALUATION
RADY CHILDREN'S HOSPITAL
MAIN CAMPUS MASTER PLAN
SAN DIEGO, CALIFORNIA

Prepared for

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Project No. SD689
October 1, 2021

GROUP DELTA

October 1, 2021

Jacobs
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Attention: Mr. Charles Smith

SUBJECT: **ADDENDUM GEOTECHNICAL INVESTIGATION**
Ground Motion Hazard Evaluation
Rady Children's Hospital, Main Campus Master Plan
San Diego, California

Mr. Smith:

We are pleased to submit this addendum geotechnical investigation report for the Rady Children's Hospital (RCH) Main Campus Master Plan renovations. This report is based on our supplemental geophysical exploration and analyses within the area of the proposed development. This report provides site-specific seismic design parameters in accordance with ASCE 7-16 based on a site-specific ground motion hazard evaluation. These values supersede the mapped design acceleration parameters presented in the referenced Geotechnical Investigation Report (Group Delta, 2021).

We appreciate this opportunity to be of continued professional service. Feel free to contact the office with any questions or comments, or if you need anything else.

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1.0 INTRODUCTION

This addendum report presents the results of the site-specific seismic hazard analyses performed in accordance with the 2019 California Building Code (CBC) and ASCE 7-16 (ASCE/SEI 7-16) for the Main Campus Master Plan Improvements at Rady Children's Hospital. The subsurface soil conditions used in this study were obtained from our non-destructive field investigation program conducted by Subsurface Surveys & Associates, Inc. (Appendix A).

Horizontal Acceleration Response Spectra (ARS) for 5-percent damping were developed for the Risk-Targeted Maximum Considered Earthquake (MCE_R), as defined by ASCE 7-16, following Chapter 21.2, by performing both probabilistic and deterministic seismic hazard analyses. Site-specific probabilistic seismic hazard analyses were performed using the computer tool OpenSHA (Field, 2003), using the Uniform California Earthquake Rupture Forecast, Version 3 (UCERF3) seismic source model. Development of the horizontal ARS was also performed using the ground motion models developed as part of the Next Generation Attenuation (NGA) – West 2 research project.

2.0 SEISMIC SETTING

The centroid of the site is at a latitude of 32.7998º north and a longitude of 117.1519º west. The area is in a region with high seismic activity. Figure 1 presents a Fault Map showing the nearby active faults. Table 1 below lists the active faults closest to the site, along with their Fault Type, Maximum Magnitude (Mw) and Site-To-Source Rupture Distance (R_{rup}). These faults are obtained primarily from the Version 3 of the Uniform California Earthquake Rupture Forecast (UCERF3) (Field et al., 2013), which is the seismic source model developed by the Working Group on California Earthquake Probabilities (WGCEP) in 2013. The UCERF3 model was subsequently adopted by the 2014 U.S. National Seismic Hazard Mapping Program (NSHM) (Petersen et al., 2014) to develop probabilistic seismic hazard maps.

Table 1. Significant Active Faults Near the Site

Fault	Fault Type	Maximum Magnitude, M_W	Site-to-Source Distance, R_{rup} (km)
Rose Canyon	Strike-Slip	7.0	5.3
Carlsbad	Reverse	6.7	24.0
Coronado Bank	Strike-slip	7.4	26.6
Oceanside alt 1	Reverse	7.2	31.0
San Diego Trough North	Strike-Slip	7.3	43.1
Elsinore (Whittier + Glen Ivy + Temecula + Julian + Coyote Mountains)	Strike-Slip	7.8	60.0
Earthquake Valley	Strike-Slip	7.0	66.2
San Jacinto (San Bernardino + San Jacinto Valley + Anza + Stepovers Combined + Coyote Creek + Borrego + Superstition Mountains)	Strike-Slip	7.8	93.3

As shown in Table 1, the closest known active seismic source to the site is the Rose Canyon fault zone, which is located about 5.3 kilometers (km) west of the site. The Rose Canyon is a strike-slip fault zone that extends from off the coast of Carlsbad down through La Jolla, and then through downtown San Diego to near the California and Mexico border.

The maximum magnitudes and scenarios adopted are consistent with the published Building Seismic Safety Council 2014 Event Set (the adopted deterministic ruptures used for the 2014 USGS NSHM (BSSC, 2015). For multi-segment faults, such as Elsinore, where different earthquake scenarios are considered, the one producing the largest magnitude was reported in the table along with its combined segments.

3.0 SITE CHARACTERIZATION

In developing site-specific ground motions, the characteristics of the soils underlying the site are an important input to evaluate the site response at a given site. In particular, the average shear wave velocity in the upper 30 meters ($V_{S,30}$), is a necessary parameter to perform seismic hazard analyses. A geophysical survey was performed at the site to characterize the subsurface condition (Appendix A).

Based on the review of the field investigation data, the average shear wave velocity in the upper 100 feet (30 meters) ($V_{S,30}$) was 494 m/s at the site. The site is classified as Site Class C per Chapter 20 of ASCE 7-16.

4.0 GROUND MOTION HAZARD ANALYSES

Site-specific ARS are developed following the procedures of Chapter 21 of ASCE 7-16. Details are discussed in the following sections.

4.1 Ground Motion Models

Site-specific ground motions are influenced by type of faulting, magnitude of characteristic earthquakes, and local soil conditions. Many ground motion models (GMMs), also referred to as ground motion prediction equations (GMPEs) have been developed to estimate the variation of spectral acceleration with earthquake magnitude and source-to-site distance, among other parameters. The Pacific Earthquake Engineering Research (PEER) coordinated a large multidisciplinary project entitled "NGA (Next Generation Attenuation)-West 2 Research Project" (Bozorgnia et al., 2014), referred to as NGA-West2. In NGA-West2, five teams have developed and presented horizontal ground motion models for shallow crustal earthquakes in active tectonic regions including Western North America. These teams are Abrahamson et al. (2014), Boore et al. (2014), Campbell and Bozorgnia (2014), Chiou and Youngs (2014), and Idriss (2014).

All five models were considered in developing the ARS at the site. Four models were assigned equal weight of 0.22, except for Idriss, which was assigned weight of 0.12, to be consistent with the adopted weighting of the USGS (2014) in developing the NSHM. The Intensity Measure (IM) provided by these horizontal ground motion models corresponds to the 50th percentile of the rotated orientation-independent horizontal component, RotD50, defined by Boore (2010).

The NGA-West2 relationships use measured values of shear wave velocity ($V_{S,30}$) as input, presented in Section above. In addition, some of the ground motion models require input for $Z_{1.0}$ (defined as the depth in meters to a shear wave velocity of V_s = 1 km/s) and $Z_{2.5}$ (defined as the depth in km to a shear wave velocity of V_s = 2.5 km/s). These two parameters are used to capture the basin effect on site response. Review of a few shear wave velocity profiles obtained from the shear-wave velocity profile database (VSPDB) (Kwak et al, 2021) that are located just west and just south of the site indicates that the local $Z_{1.0}$ value is shallow, ranging from 15 meters to about 50 meters. Basin parameters from SCEC/Havard Community Velocity Model (CVM) (version 11.9) obtained from OpenSHA (Fields, 2003) were also evaluated and found to be very comparable with the nearby site-specific data. Therefore, the SCEC/Harvard CVM basin factors of $Z_{1.0}$ = 40 m and $Z_{2.5}$ = 0.22 km have been adopted for use in analyses.

4.2 Probabilistic Seismic Hazard Analyses

Site-specific Probabilistic Seismic Hazard Analyses (PSHA) were performed using the computer tool OpenSHA (Fields, 2003), using the Uniform California Earthquake Rupture Forecast, Version 3 (UCERF3) seismic source model and the updated NGA-West2 ground motion models. Uniform hazard horizontal ARS were developed up to a period of 10 seconds. All spectra were developed for 5-percent damping. Figure 2 presents the results of probabilistic seismic hazard spectrum. The median (RotD50) ground motion was adjusted to the maximum rotated component of ground motion (RotD100) using the factors recommended by Shahi and Baker (2014).

4.3 Deterministic Seismic Hazard Analyses

Site-specific Deterministic Seismic Hazard Analyses (DSHA) were performed based on the characteristics of earthquake scenarios identified as predominant contributors to the regional seismic hazard. Pertinent characteristics of the earthquake scenarios include parameters such as distance from the site to the causative fault and the maximum magnitude of earthquake associated with the fault. The effects of local soil conditions ($V_{S,30}$) and the mechanism of faulting are accounted for in the ground motion models as well.

DSHAs were performed for the Rose Canyon, Carlsbad, and Coronado Bank sources identified in Table 1. The NGA West2 GPMEs were used to develop a 5-percent damped spectral ARS for each source. A plot of the DSHA for the project site is shown in Figure 3. The Rose Canyon fault is the controlling seismic source at all spectral periods. According to ASCE 7-16 Section 21.2.2 and Supplement 1 of ASCE 7-16, the deterministic MCE_R, which corresponds to the 84th-percentile (median plus one standard deviation), 5-percent damped spectral response accelerations in the direction of maximum horizontal response at any spectral period, must not be lower than deterministic lower limit. Therefore, the 84th-percentile spectral values obtained from the GMPEs are used to develop the deterministic spectrum. The ground motions were adjusted to the maximum rotated component of ground motion using the Shahi and Baker (2014) factors. Figure 4 shows the results of our DSHA along with the ASCE 7-16 deterministic lower limit spectrum.

4.4 Determination of Site-Specific Acceleration Response Spectra

Development of the site-specific MCE_R ARS as defined by ASCE 7-16, Chapter 21.2, was performed using the seismic hazard analysis procedures described in the previous sections. In accordance with ASCE 7-16 Section 21.2.3, the site-specific MCE_R ARS is taken as the lesser of the probabilistic and deterministic MCE_R spectra at all spectral periods. In addition, the site-specific MCE_R cannot be not less than 150-percent of the site-specific design spectrum in Section 21.3.

Figure 5 represents the 5-percent damped horizontal MCE_R ARS for the site. The site-specific Design Earthquake spectrum is equal to two-thirds of the site-specific MCE_R spectrum, although it is not less than 80 percent of the design spectrum developed per Section 21.3. Figure 6 presents both the MCE_R and the Design Earthquake spectra along with the tabulated values.

4.5 Site-Specific Design Acceleration Parameters

The short period design spectral acceleration (S_{DS}) and 1-second period design spectral acceleration (S_{D1}) parameters were determined in accordance with ASCE 7-16 Section 21.4. The parameter S_{DS} is taken as 90-percent of the maximum spectral acceleration from the site-specific spectrum at periods between 0.2 and 5 seconds. The parameter S_{D1} is taken as the maximum of the product between period and spectral acceleration for periods from 1 to 2 seconds for sites with a $V_{S,30}$ greater than 365 m/s. The parameters S_{MS} and S_{M1} shall be taken as 1.5 times S_{DS} and S_{D1} respectively. The values obtained shall not be less than 80-percent of the values determined in accordance with ASCE 7-16, Section 11.4.3 for S_{MS} and S_{M1} and Section 11.4.5 for S_{DS} and S_{D1}. Table 2 presents the site-specific design acceleration parameters.

Table 2. Site-Specific Seismic Design Acceleration Parameters

Design Parameters	Site-Specific Seismic Design Parameters (ASCE 7-16 Section 21.4)
Site Class	C
S_{MS} (g)	1.392
S_{M1} (g)	0.512
S_{DS} (g)	0.928
S_{D1} (g)	0.341

5.0 LIMITATIONS

This report was prepared using the degree of care and skill ordinarily exercised, under similar circumstances, by reputable geotechnical consultants practicing in similar localities. No warranty, express or implied, is made as to the conclusions and professional opinions included in this report.

The findings of this report are valid as of the present date. However, changes in the condition of a property can occur with the passage of time, whether due to natural processes or the work of man on this or adjacent properties. In addition, changes in applicable or appropriate standards of practice may occur from legislation or the broadening of knowledge. Accordingly, the findings of this report may be invalidated wholly or partially by changes outside our control. Therefore, this report is subject to review and should not be relied upon after a period of three years.

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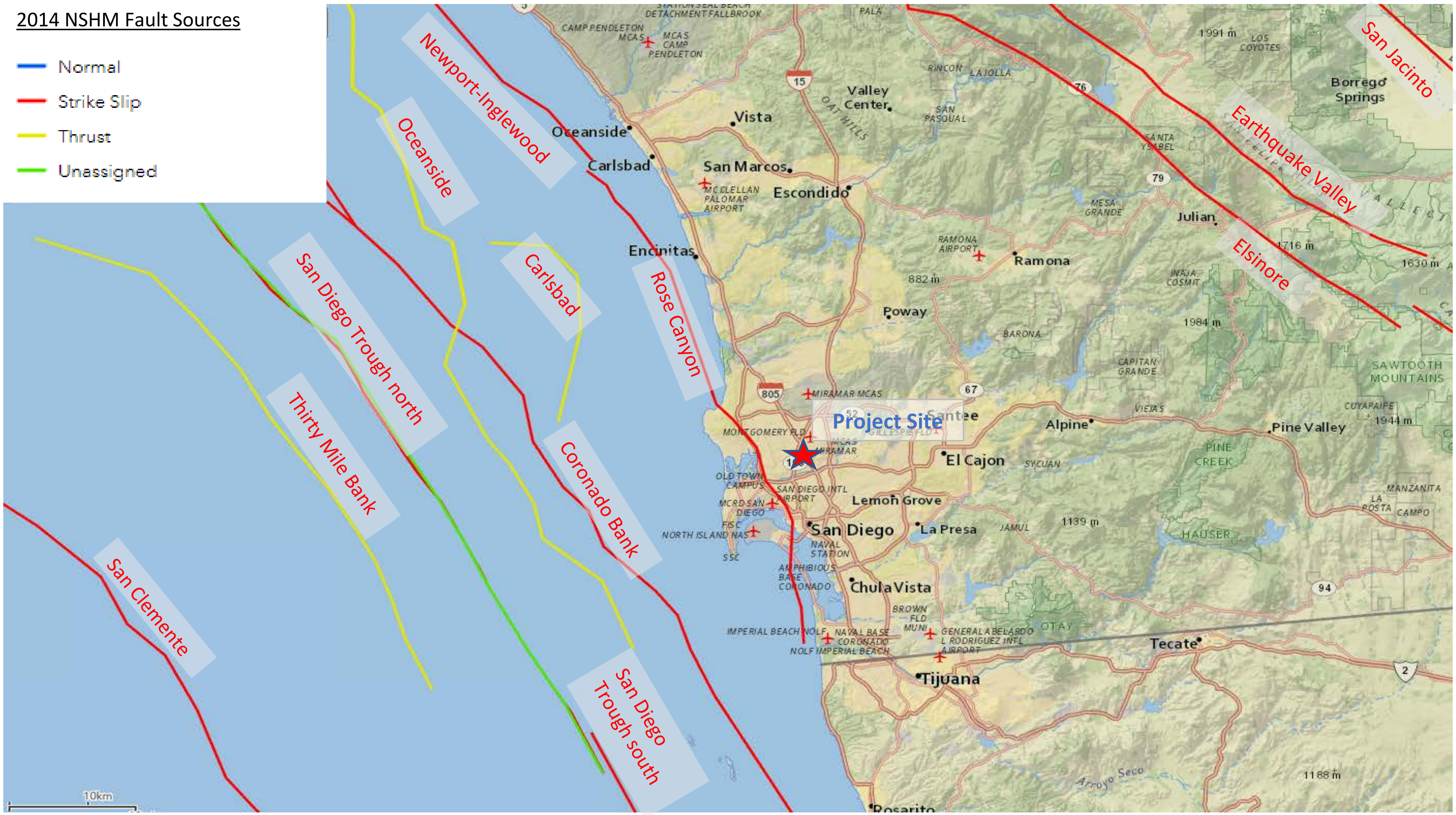
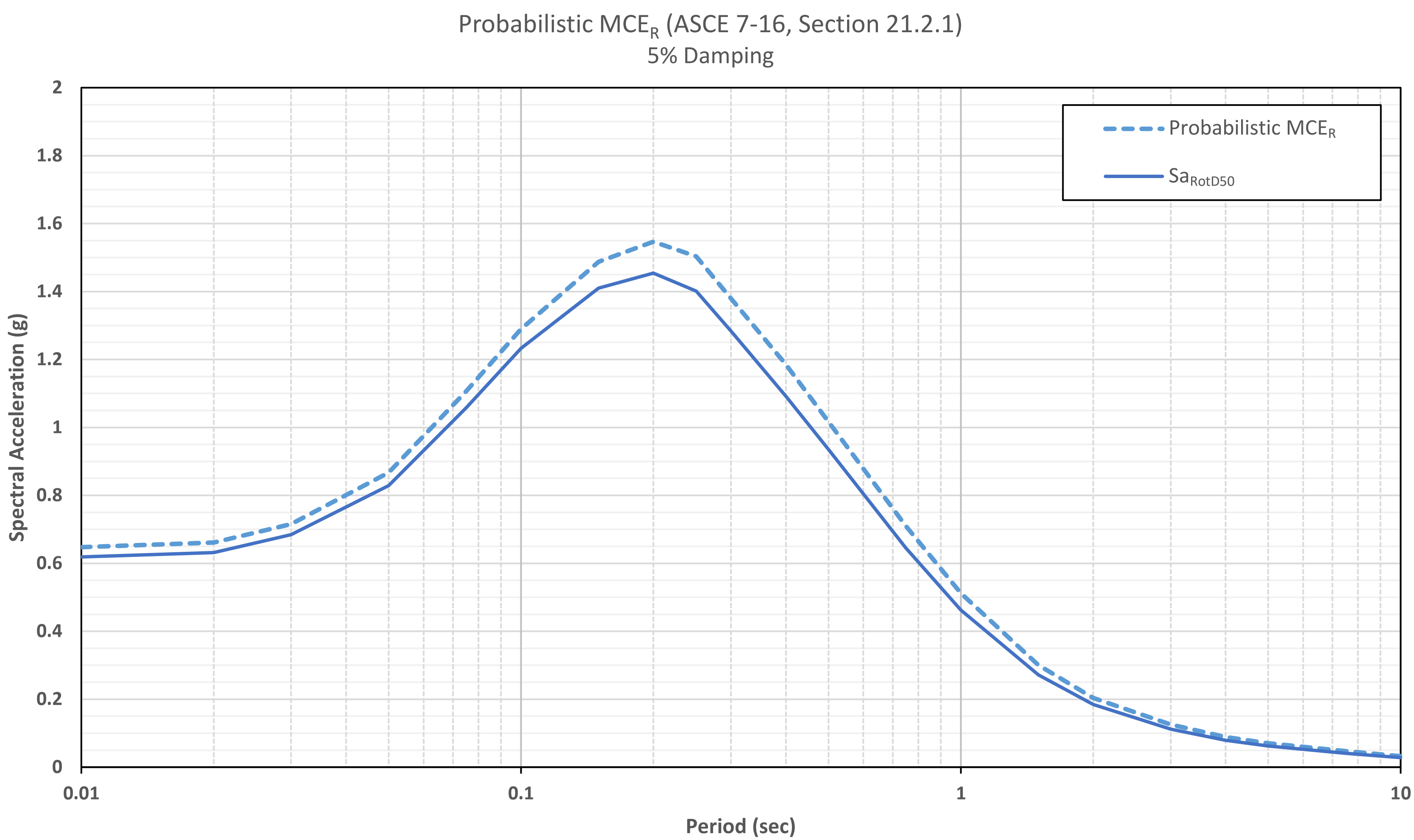
FIGURES

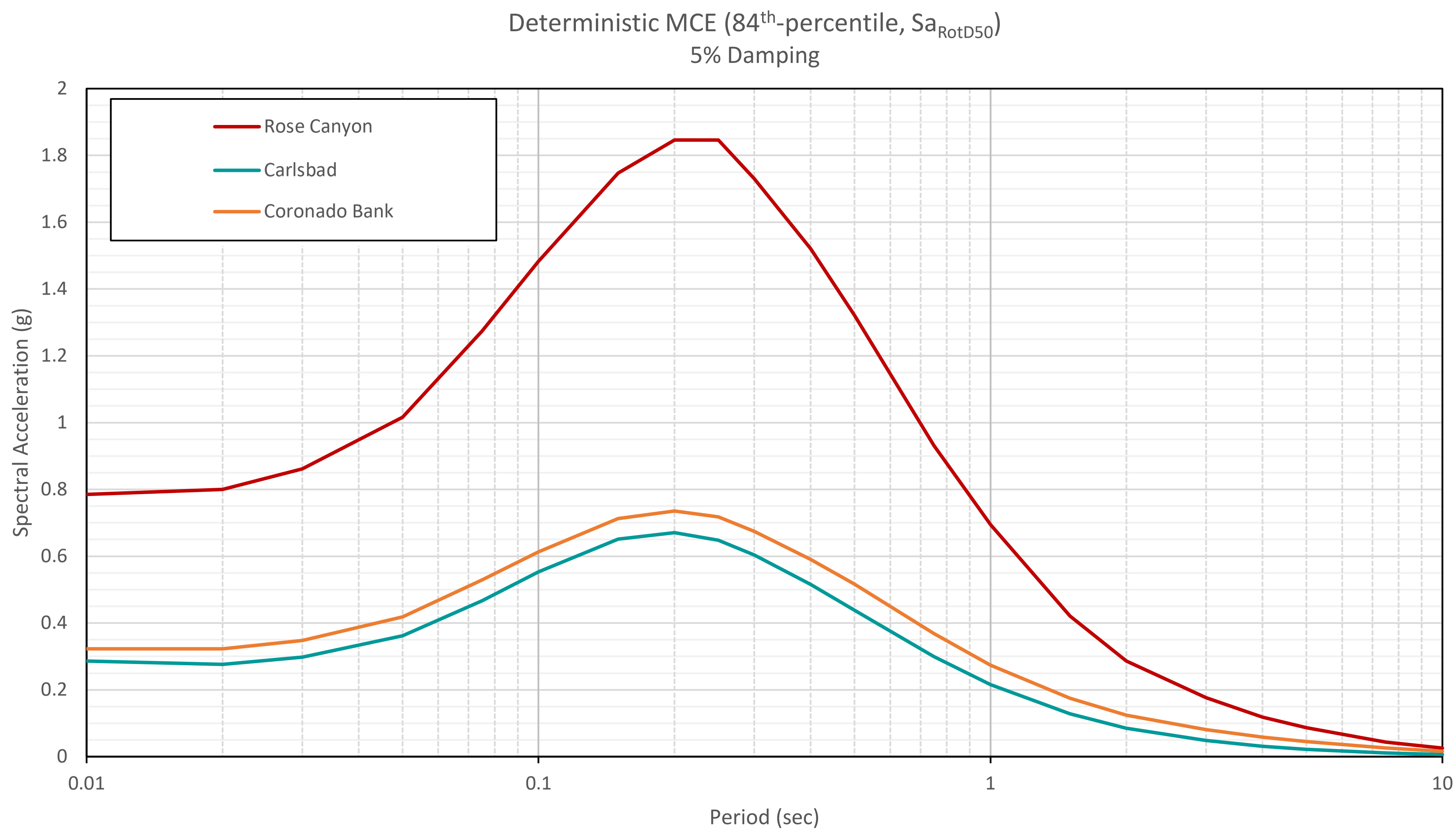


Reference: USGS Quaternary Faults, NSHM 2014 Fault Sources https://usgs.maps.arcgis.com/apps/webappviewer/index.html

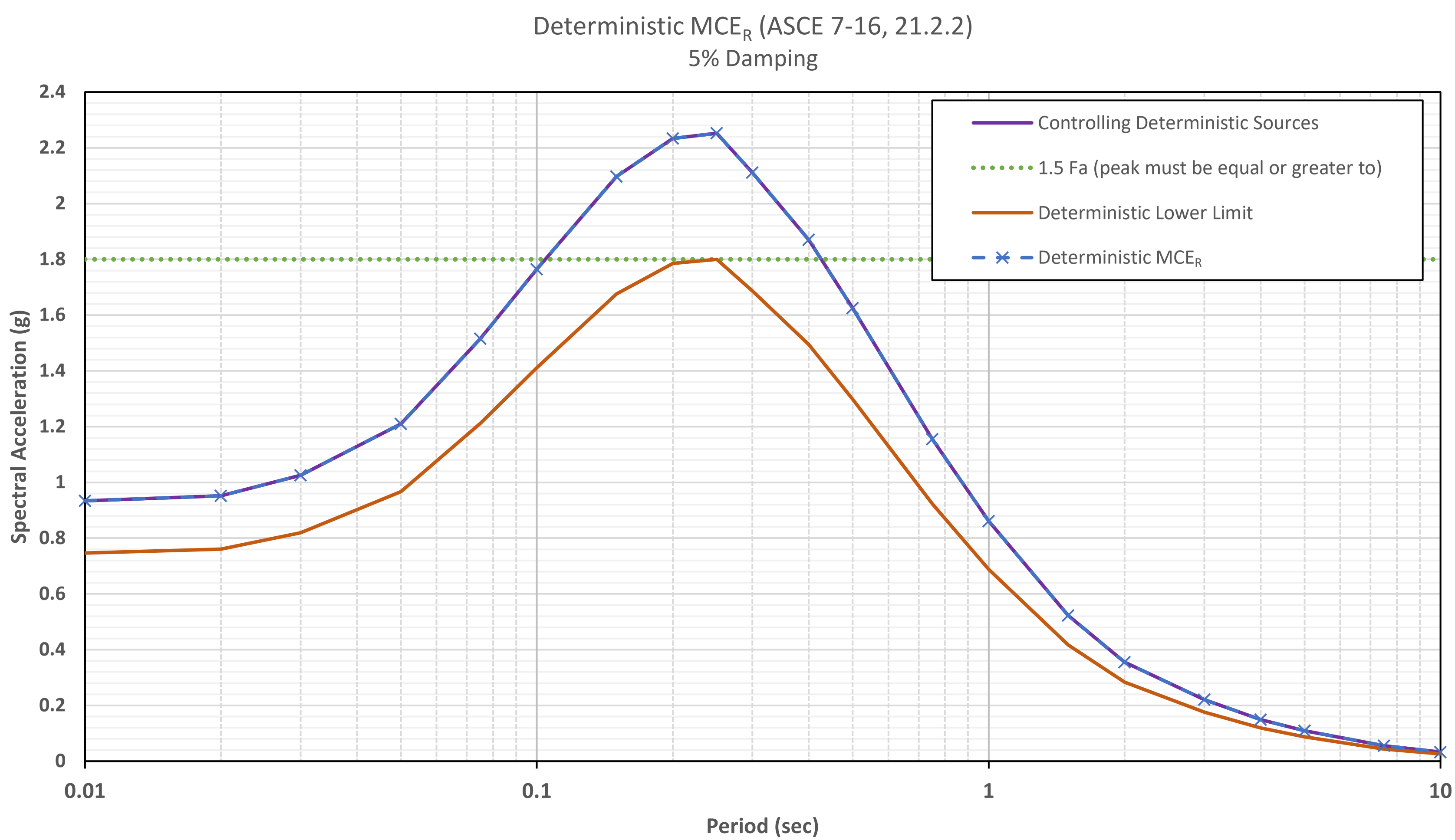
PROJECT NAME	FIGURE NAME	GROUP DELTA	
Rady Children's Hospital Main Campus Master Plan Site-Specific Ground Motion Study San Diego, CA	**Seismic Source Fault Map (2014 NSHM)**	PROJECT NUMBER SD689	FIGURE NUMBER 1



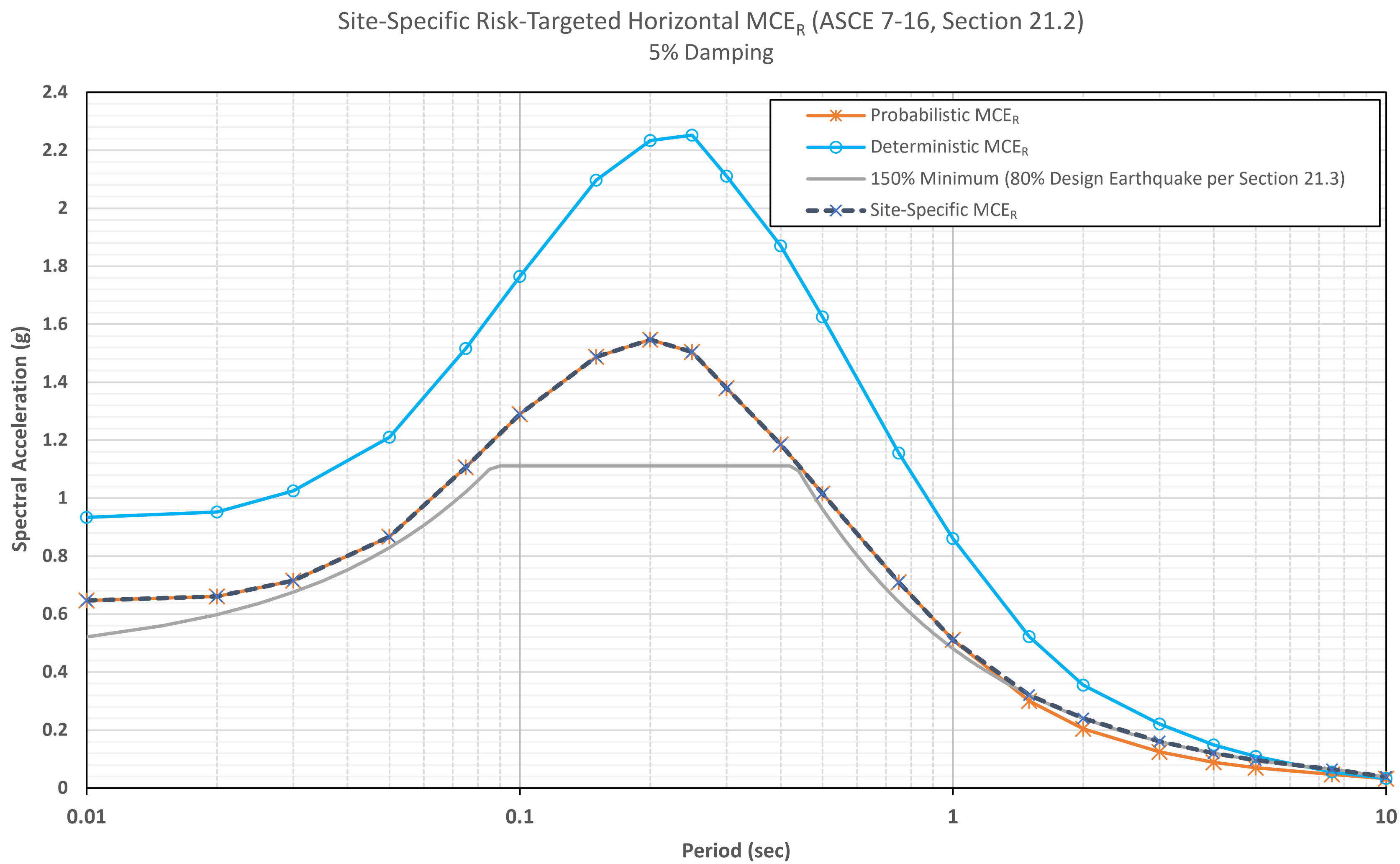
PROJECT NAME	FIGURE NAME	GROUP DELTA	
Rady Children's Hospital **Main Campus Master Plan** **Site-Specific Ground Motion Study** **San Diego, CA**	**Probabilistic MCE$_R$** **Acceleration Response Spectrum**	PROJECT NUMBER SD689	FIGURE NUMBER 2



PROJECT NAME	FIGURE NAME	PROJECT NUMBER	FIGURE NUMBER
Rady Children's Hospital **Site-Specific Ground Motion Study** **San Diego, CA**	**Deterministic** **Acceleration Response Spectra**	SD689	3

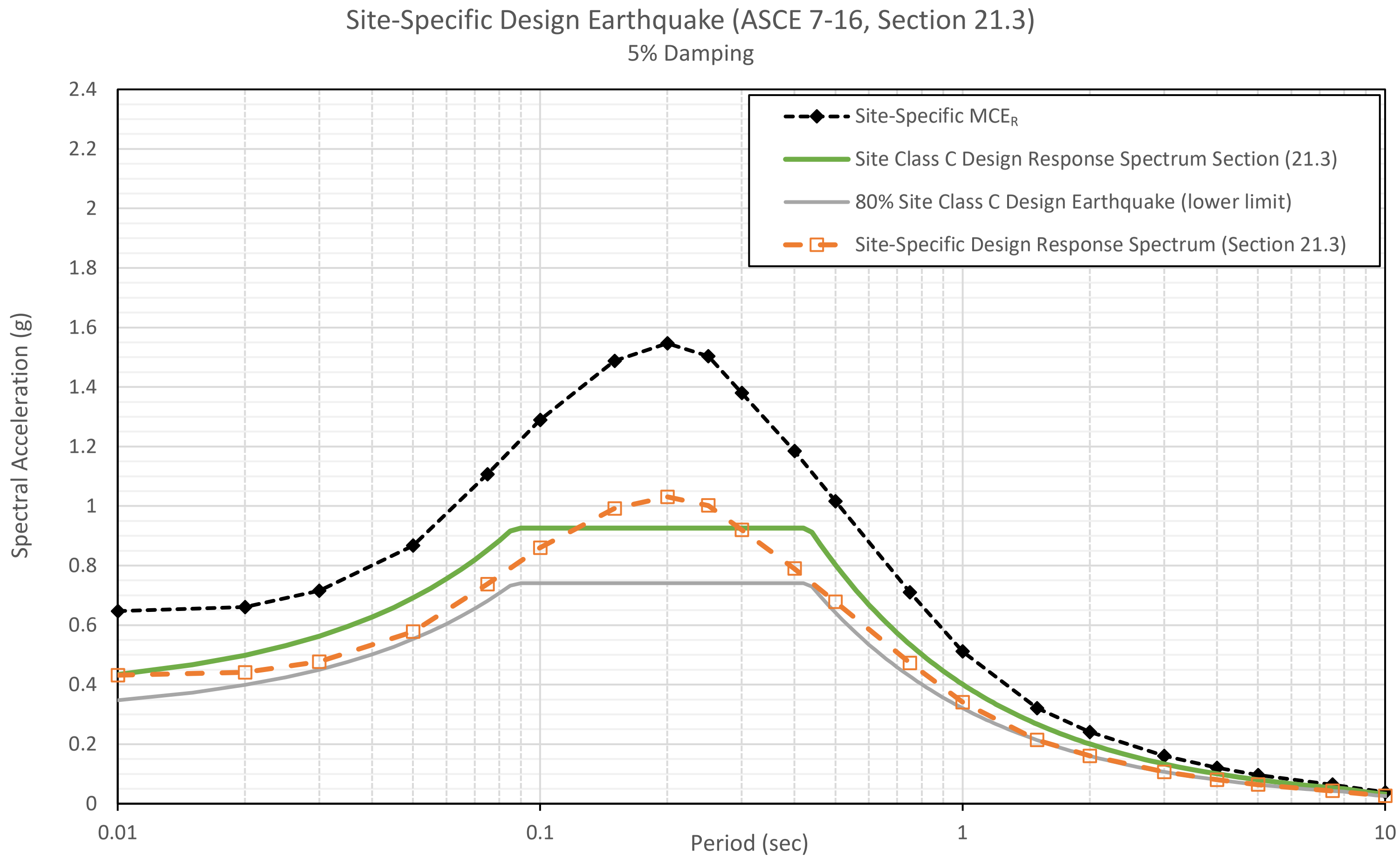


PROJECT NAME	FIGURE NAME	GROUP DELTA	
Rady Children's Hospital **Main Campus Master Plan** **Site-Specific Ground Motion Study** **San Diego, CA**	**Deterministic MCE$_R$** **Acceleration Response Spectra**	PROJECT NUMBER SD689	FIGURE NUMBER 4



PROJECT NAME	FIGURE NAME	GROUP DELTA	
Rady Children's Hospital **Main Campus Master Plan** **Site-Specific Ground Motion Study** **San Diego, CA**	**ASCE 7-16 Site-Specific MCE_R** **Acceleration Response Spectra**	PROJECT NUMBER SD689	FIGURE NUMBER 5

ASCE 7-16 MCE_R and Design Earthquake		
Period	Design	MCE_R
(sec)	Sa (g)	Sa (g)
0.01	0.432	0.648
0.02	0.441	0.662
0.03	0.477	0.716
0.05	0.578	0.867
0.075	0.738	1.107
0.1	0.860	1.290
0.15	0.992	1.488
0.2	1.031	1.547
0.25	1.002	1.503
0.3	0.920	1.380
0.4	0.790	1.185
0.5	0.678	1.017
0.75	0.473	0.710
1	0.341	0.512
1.5	0.214	0.321
2	0.160	0.241
3	0.107	0.161
4	0.080	0.120
5	0.064	0.096
7.5	0.043	0.065
10	0.026	0.039



Site-Specific Design Acceleration Parameters (ASCE 7-16 Section 21.4)

S_{DS} = 90% of the peak S_a from T =0.2 to 5 s (not less than 80% of mapped S_{DS})

S_{D1} = Peak T*S_a between periods of 1 second and 2 seconds (not less than 80% of mapped S_{D1})

S_{DS} = 0.928 **S_{D1} =** 0.341

PROJECT NAME	FIGURE NAME	GROUP DELTA	
Rady Children's Hospital Main Campus Master Plan Site-Specific Ground Motion Study San Diego, CA	**ASCE 7-16 Site-Specific Design Earthquake and Site-Specific Design Acceleration Parameters**	PROJECT NUMBER SD689	FIGURE NUMBER 6

APPENDIX A
GEOPHYSICAL EXPLORATION

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September 20, 2021

Attn: Matt Fagan

Re: Seismic Survey Summary Report
Rady Children's Hospital

This report covers the results of a seismic shear wave survey performed at Rady Children's Hospital in San Diego, California. The main objective was to record low frequency surface wave data to determine shear wave velocity to a depth of 100 feet, if possible. This survey is part of a larger geotechnical investigation for a proposed multi-story medical building.

The survey was conducted on September 15, 2021. Data was recorded along one seismic traverse, 276 feet in length. The location and orientation of the traverse is shown on Figure 1.

GEOLOGIC SETTING

A review of the Geologic Map of the San Diego 30' x 60' Quadrangle, California Geological Survey, Kennedy 2005, indicates Very old paralic deposits Qvop, middle to early Pleistocene, underlie the survey area. This geologic unit is primarily composed of siltstone, sandstone, and conglomerate.

DATA ACQUISITION AND FIELD METHODS

Seismic data were recorded with a Seistonix RAS 24 digital seismograph using 4.5 Hz geophones. The standard spread layout used 24 geophones with a 12-foot spacing. Five shotpoints were used, two off each end (10 and 20-foot offset) and one at the center of the spread.

Surface wave energy for the active source dat was created by sledge hammer impacts on a metal plate. The signal enhancement feature of the seismograph allowed returns from repeated hits to be stacked, thus improving the signal. Each record was stored digitally on an internal hard disk.

SEISMIC METHODS

MASW – The Multi-channel Analysis of Surface Waves method uses low frequency surface waves, commonly referred to as "ground roll", to extract shear wave (S-wave) velocity data verses depth in the subsurface. This information is commonly used for soil classification, tower and foundation design, and seismic response spectra calculations.

This method does not measure shear wave velocity directly. Rather, dispersion curves are extracted from the raw multi-channel field records and inverted to produce a one-dimensional S-wave velocity profile.

Additional surface wave data was recorded using the passive-source MAM method as described below.

MAM - The Microtremor Analytical Method uses ambient low frequency seismic noise (vibrations) generated mostly by surrounding car, truck, and bus traffic.

This method requires a relatively steady stream of background noise, produced from different directions, to work properly. When these conditions are met, results typically produce greater penetration depth compared to MASW.

SEISMIC PROCESSING AND INVERSION MODELING

Surface wave data was processed with SeisImager/SW software from Geometrics Inc. The software calculates shear wave velocity by mathematical inversion of the dispersive phase velocity of surface waves. In this application, Raleigh waves (also referred to as "ground roll") are the main surface waves of interest. A summary of the steps involved is provided below.

Standard time-distance field records are converted from time domain to frequency domain using a phase velocity- frequency transformation. This yields dispersion curve plots of frequency (Hz) verses phase velocity in (ft/sec). A wave equation module then performs inversion modeling to produce plots of shear wave velocity verse depth.

SUMMARY OF RESULTS

Shear wave profiles from MAM and MASW processing are displayed on Figures 2 and 3. Results from the MASW data set were fair to poor quality, primarily due to noise and interference from vehicles continuously entering and leaving the parking lot.

However, the steady background of traffic and on-site generator noise from various directions enhanced the MAM data, both in quality and depth.

The shear wave velocity curves from both methods show similar results. The modeling results indicate a steady increase in velocity verses depth from 23 to 100 feet.

The calculated Vs100 ft values are provided below:

MAM Vs100 ft = 1621.2 ft/s (Root Mean Square error = 4.3%)
MASW extrapolated Vs100 ft = 1572.0 ft/s (RMS error = 4.1%)

These values are within the Class C soil range of 1200-2500 ft/sec using the Uniform Building Code (2001) guidelines.

All data acquired during this survey is considered confidential and is available for review by your staff at any time. We appreciate the opportunity to participate in this project. Please call if there are any questions.

PAWalen

Phillip A. Walen
Senior Geophysicist
CA Registration No. GP917

Seismic Survey Location Map

Rady Children's Hospital -- San Diego, California

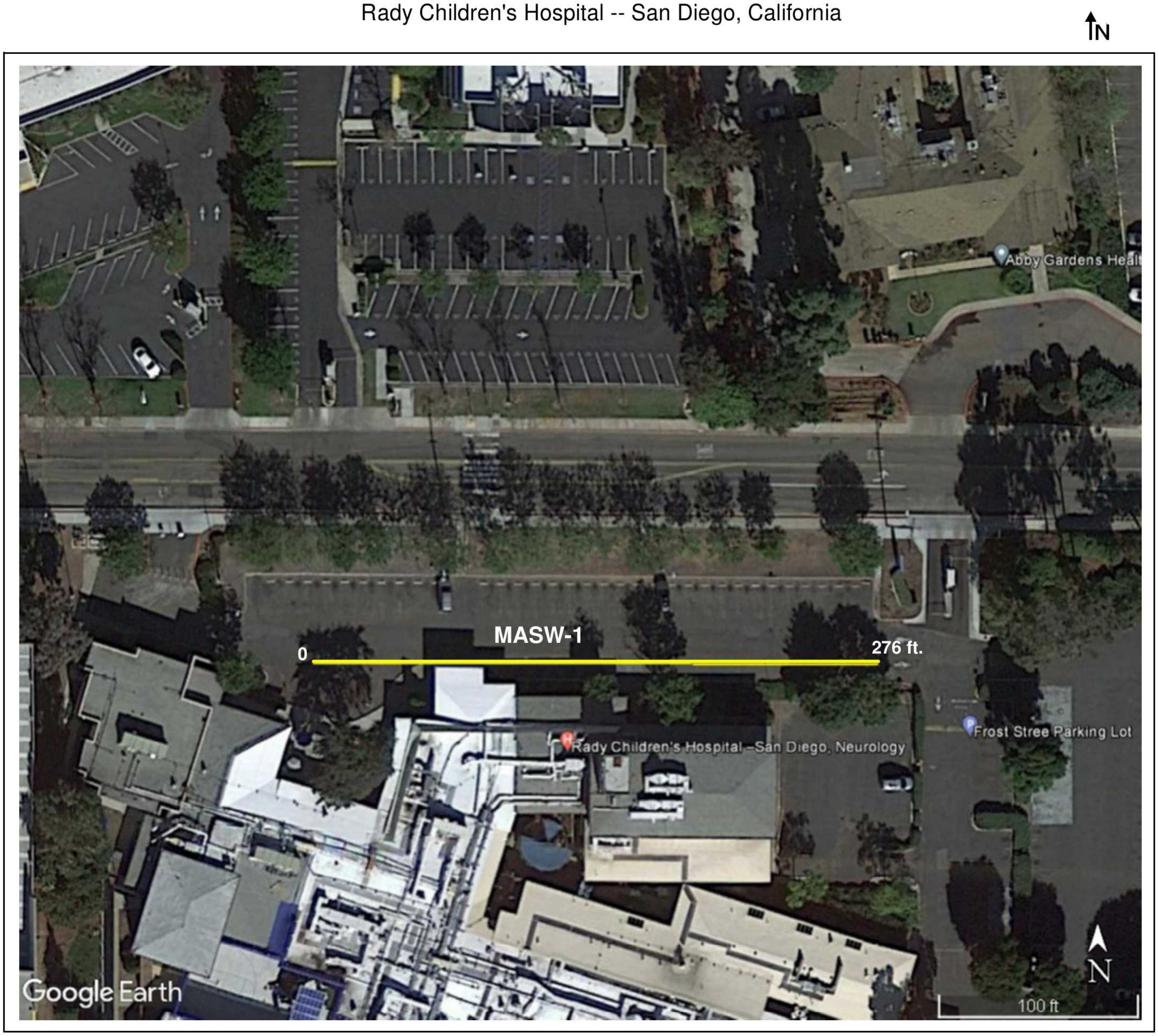
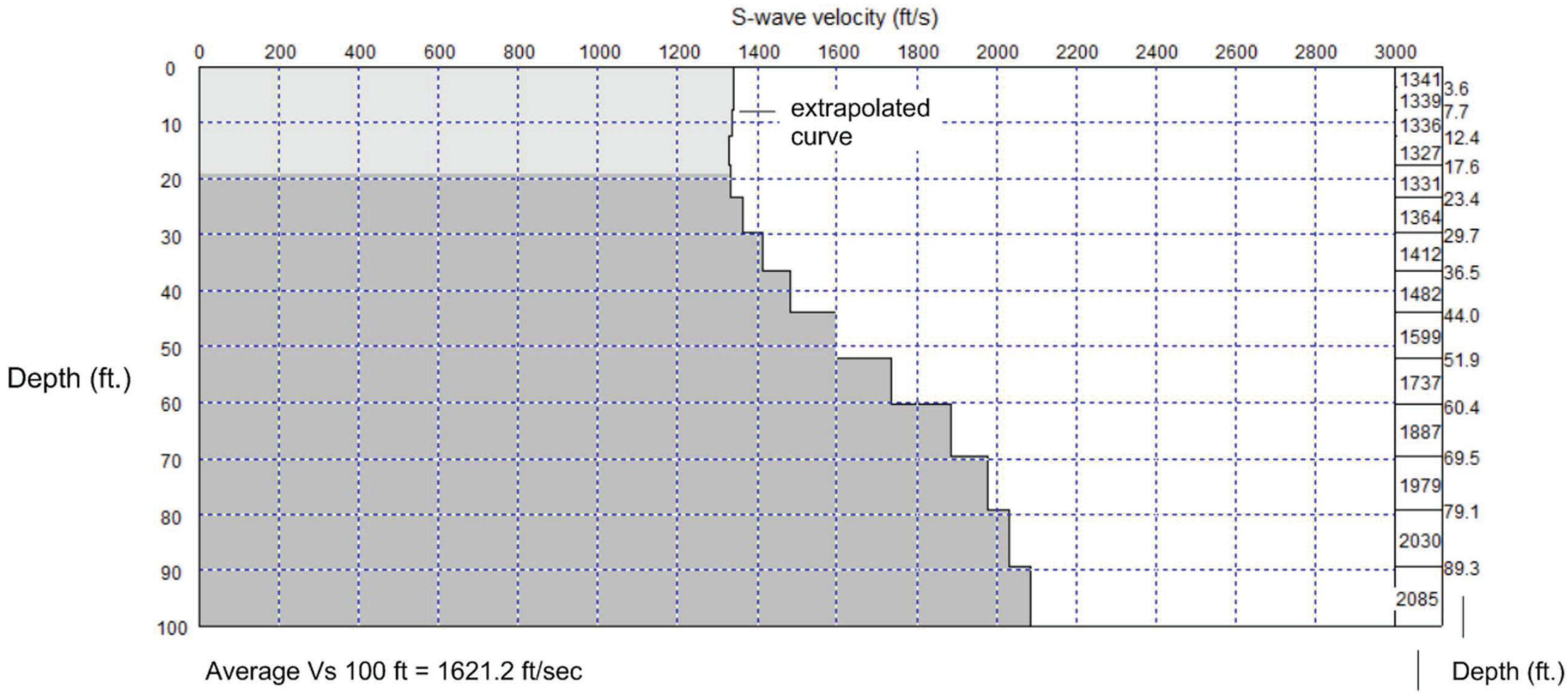


Figure 1

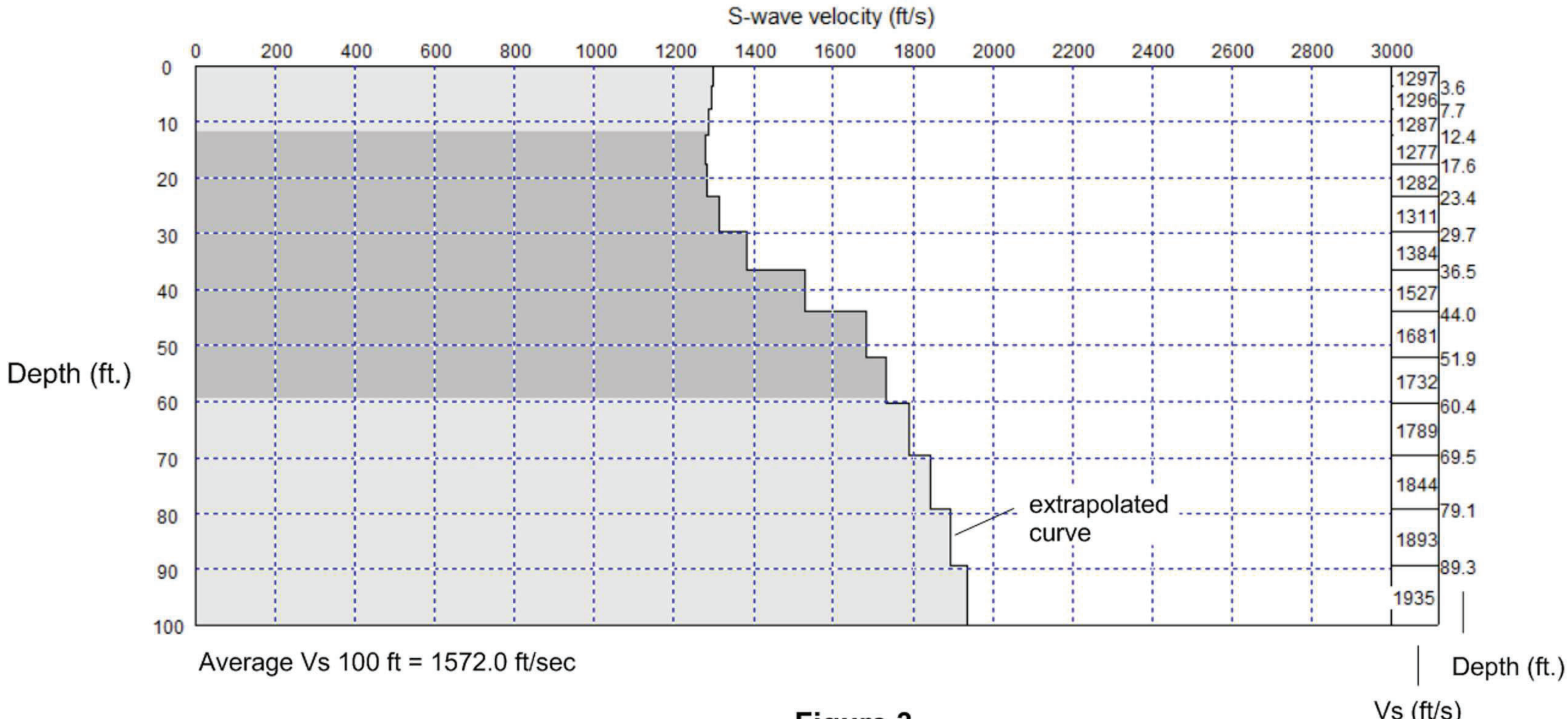
MAM Model: Vs verses Depth -- Line 1



Average Vs 100 ft = 1621.2 ft/sec

Figure 2

MASW Model: Vs verses Depth -- Line 1



Average Vs 100 ft = 1572.0 ft/sec

Figure 3

EXPLANATION:

B-20 Approximate locations of the 20 exploratory borings completed for this investigation, with Depth of Fill (Df) shown (Group Delta, 2021).

Approximate location of the seismic refraction survey line for average shear wave velocity determination (Vs_{30}).

GROUP DELTA

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PROJECT NAME Rady Children's Hospital Jacobs	PROJECT NUMBER SD689
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	FIGURE NUMBER A-1

EXPLORATION PLAN (NORTH)