国際共同研究
2019-W05

京都大学 防災研究所
Disaster Prevention Research Institute
Kyoto University

強震観測点のサイト特性と地盤構造抽出手法の高度化に関する日米共同研究

US-Japan Joint Research on Improving Evaluation Methods for Site Amplification and Underground Structures

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We provide the final non-interpretive report with an extended due date of 31 January 2023 describing Project 2019-W05, which was designed to characterize seismic site conditions at strong motion (SM) earthquake recording stations in southern California for the research period of 1 April 2019–31 March 2022 (Figure 1). In this report, we briefly show examples of processed field recorded data from site characterization surveys performed at each of the seven SM stations within this study (Figures 2–8).

The coupling of SM site factors with seismic site conditions, based on estimations of the *S*-wave velocity (V_S; as well as the time-averaged V_S of the upper 30 m from the surface, V_{S30}) recorded at the SM stations are traditionally considered as key inputs to robustly describe the behavior (esp., site response) of ground shaking for past and future earthquakes (Boore et al., 1993; Borcherdt, 1994). Thus, variations in near-surface V_S will have a strong impact on the characteristics of ground shaking and hence, fundamentally affect seismic hazards (Kramer, 1996; Frankel *et al.*, 1996; Petersen *et al.*, 2020; 2021). Using *in-situ* invasive and noninvasive methods developed and refined by the PI and other United States-based collaborators (Yong *et al*., 2013; Martin *et al*., 2014; 2017; Yong *et al*., 2019; Stephenson *et al*., 2022), active- and passive-source seismic recordings were acquired during field surveys conducted 3–9 March 2020 and 13–19 March 2022. The Japan-based DPRI members were not able to participate in person for either period because of travel restrictions relating to the COVID-19 pandemic. Although both situations were suboptimal, the PI and the U.S.-based collaborators were able to proceed by adjusting the planned efforts accordingly. In summary, seven regionally diverse SM stations, operated by two real-time earthquake monitoring networks (Anza, code: AZ; Southern California Seismographic Network or SCSN, code: CI), were surveyed to model the site V_S profiles and determine V_{S30}. Based on the map of Figure 1 in Fletcher and Boatwright (2019) (also in this report as Figure 1), we selected stations from their mapped locations, which suggest that our stations are situated on representative conditions of soil or rock substrate. Logistically, the proposed methods to be applied at each of these sites also appeared to be relatively easy to carry out. Piñon Flats Observatory (AZ.PFO, Figure 2) and two other stations (Keenwild, AZ.KNW, Figure 3; and Red Mountain, AZ.RDM, Figure 4) are sited on rock-like conditions in the mountainous Anza region; four sites (Elmore Ranch, CI.ERR, Figure 5; Imperial, CI.IMP, Figure 6; Shaffner Ranch, CI.SNR, Figure 7; and Westmoreland, CI.WMD, Figure 8) are on soil conditions in the sedimentary basin of the Imperial Valley. All sites were primarily surveyed using non-invasive (surface-based) body- and/or surface-wave methods that include: active-source surface array-based techniques consisting of *S*-wave refraction and multi-channel spectral analysis of surface waves ($\text{MAS}_\text{L}\text{W}$ and $\text{MAS}_\text{R}\text{W}$; Love and Rayleigh waves, respectively) techniques; three-component passive-source recordings intended for analyses using the spatial auto-correlation (SPAC) and the extended variant (ESAC) methods; and, microtremor-based horizontal-vertical spectral-ratio (mHVSR) analyses (Gomez *et al*., 2022). An invasive active-source P-S suspension down-hole logging test was also performed at PFO.

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Figures:

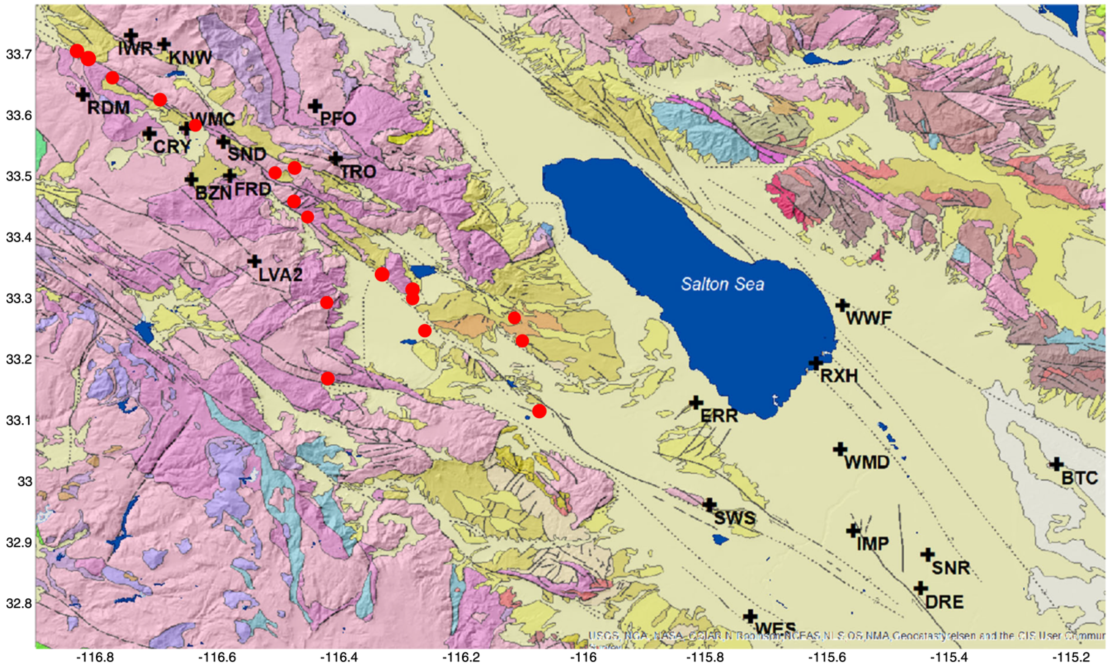

Figure 1. Map of geology in the region of Anza and the Imperial Valley, California, as shown by Fletcher and Boatwright (2019) (with permission from authors). Pink color shades generally denote rock conditions and yellow shades are sedimentary deposits. Red dots represent 18 earthquake epicenters used in the Fletcher and Boatwright (2019) study. Black crosses represent 21 earthquake monitoring stations of the Anza Network (network code: AZ) and Southern California Seismographic Network (SCSN, network code: CI); in this project, seven stations were surveyed, including: AZ.KNW, AZ.RDM, AZ.PFO, CI.ERR, CI.IMP, CI.SNR, and CI.WMD.

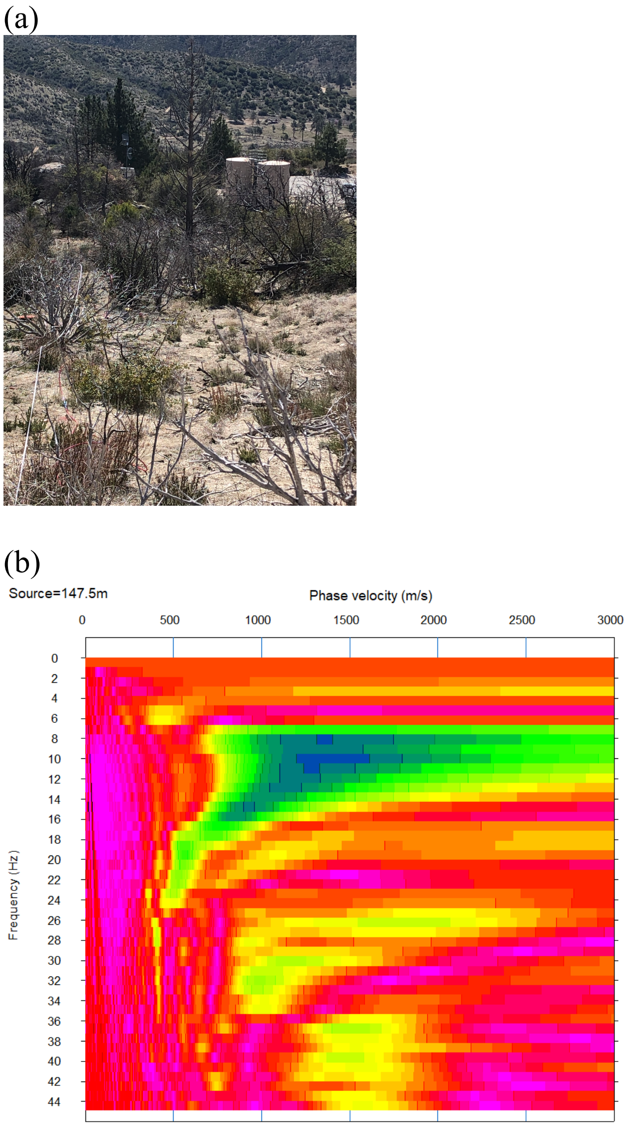

Figure 2. (a) Photo of site conditions at AZ.KNW (Photo credit: Jose Gomez); (b) Plot of MAS_LW dispersion data in frequency (Hz) and phase velocity (m/s). In addition to three-component passive-source recordings intended for microtremor-based horizontal-vertical spectral-ratio (mHVSR) analyses, three active-source surface array-based methods consisting of *S*-wave refraction and multi-channel spectral analysis of surface wave (MAS_LW and MAS_RW; Love and Rayleigh waves, respectively) techniques were performed at station AZ.KNW (33.71410, –116.71190) located on "rock" (mountain ridge-top) conditions at the United States Forest Service Keenwild Helitak property in the Anza area. Figure 2b shows sample Love-wave dispersion data based on site recordings using the MAS_LW technique.

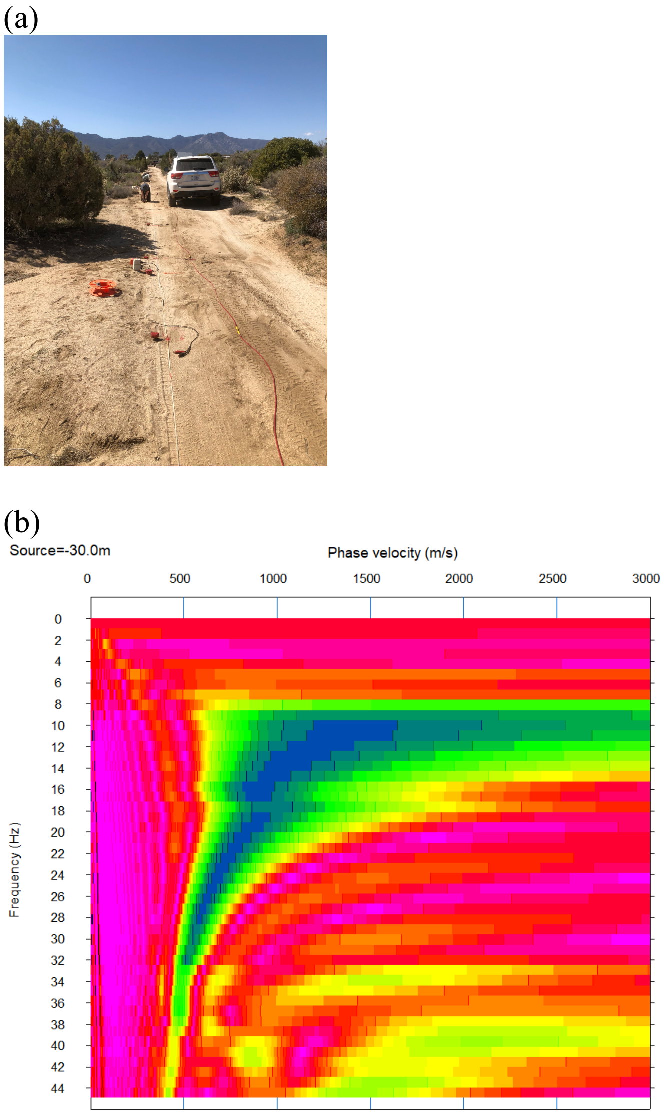

Figure 3. (a) Photo of site conditions nearby AZ.PFO (Photo credit: Jose Gomez); (b) Plot of MAS$_{\mathrm{L}}$W dispersion data in frequency (Hz) and phase velocity (m/s). In addition to three-component passive-source recordings intended for microtremor-based horizontal-vertical spectral-ratio (mHVSR) analyses, two active-source surface array-based methods consisting of *S*-wave refraction and multi-channel spectral analysis of surface wave (MAS$_{\mathrm{L}}$W; Love waves) techniques were performed at station AZ.PFO (33.6300, –116.84780) located on “rock” (mountain-nested low-grade slope) conditions at the University of California San Diego Piñon Flat property in the Anza area. Figure 3b shows sample Love-wave dispersion data based on site recordings using the MAS$_{\mathrm{L}}$W technique.

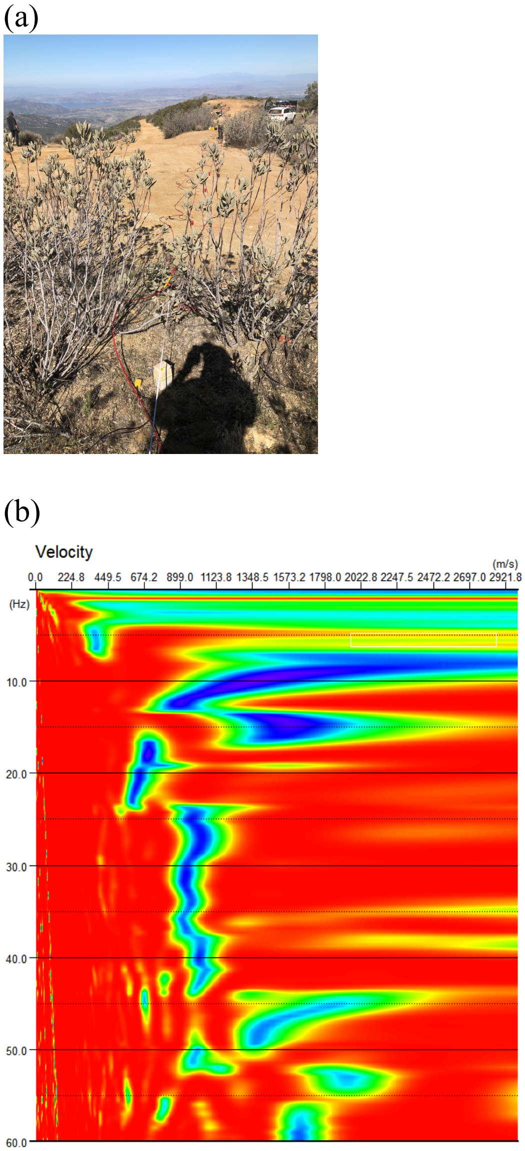

Figure 4. (a) Photo of site conditions at AZ.RDM (Photo credit: Jose Gomez); (b) Plot of MAS_RW dispersion data in frequency (Hz) and phase velocity (m/s). In addition to three-component passive-source recordings intended for microtremor-based horizontal-vertical spectral-ratio (mHVSR) analyses, four active-source surface array-based methods consisting of *P*- and *S*-wave refraction and multi-channel spectral analysis of surface wave (MAS_LW and MAS_RW; Love and Rayleigh waves, respectively) techniques were performed at station AZ.RDM (33.6300, –116.84780) located on “rock” (mountain ridge-top) conditions at the United States Forestry Service Red Mountain property in the Anza area. Figure 4b shows sample Rayleigh-wave dispersion data based on site recordings using the MAS_RW technique.

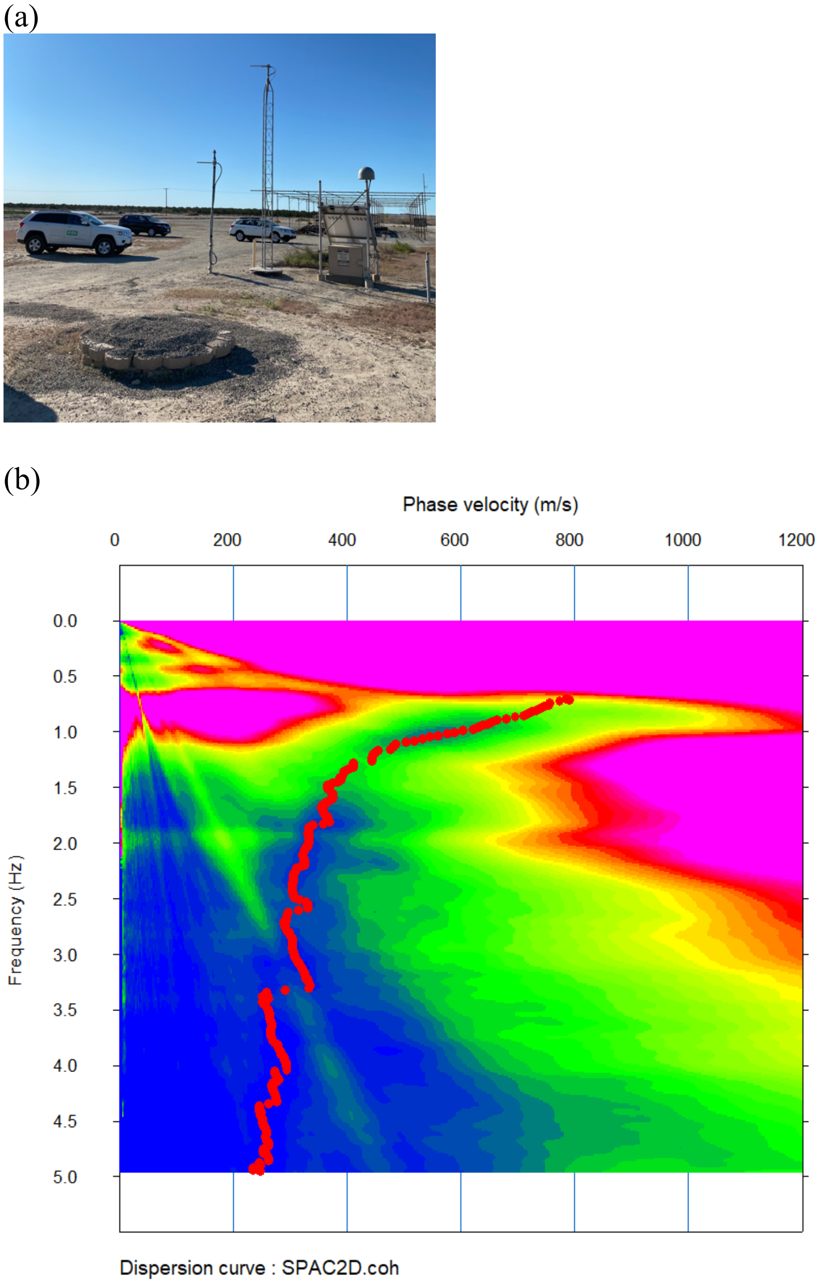

Figure 5. (a) Photo of site conditions at CI.ERR (Photo credit: Jose Gomez); (b) Plot of SPAC dispersion data in frequency (Hz) and phase velocity (m/s); an algorithm-based automatically picked maximum amplitude curve is included. In addition to three-component passive-source recordings intended for microtremor-based horizontal-vertical spectral-ratio (mHVSR) analyses, an active-source surface linear array-based method consisting of the multi-channel spectral analysis of surface wave (MAS$_{\text{R}}$W; Rayleigh waves) technique and a passive-source surface nested-circular array-based techniques using microtremor array procedures were performed at station CI.ERR (33.11645, –115.82271) located on “soil” (sedimentary basin) conditions at the Elmore Desert Ranch property in the Imperial Valley. Figure 5b shows sample Rayleigh-wave dispersion data based on site recordings using the SPAC technique.

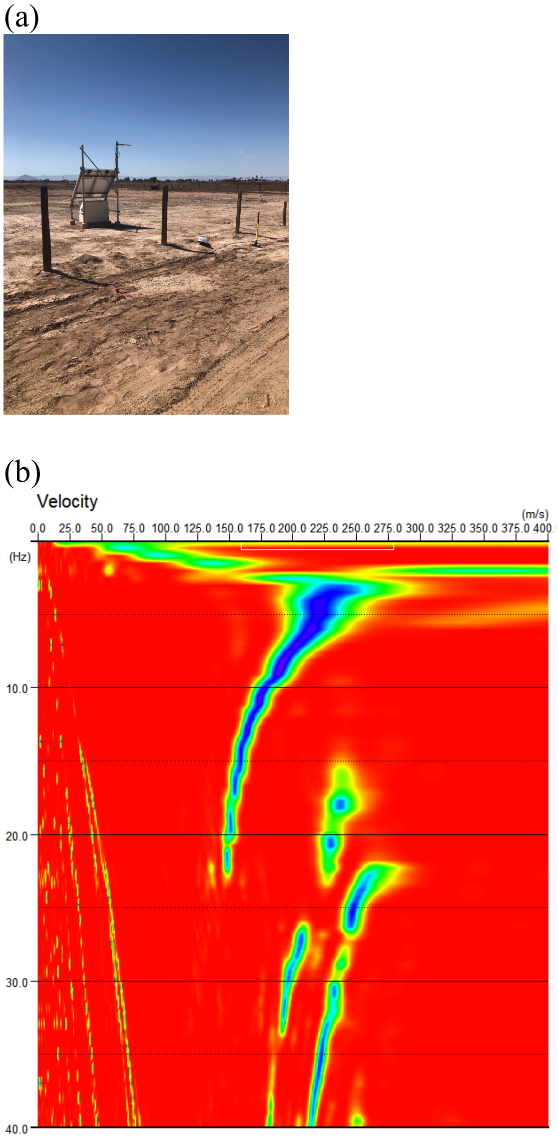

Figure 6. (a) Photo of site conditions at CI.IMP (Photo credit: Jose Gomez); (b) Plot of MAS$_\text{R}$W dispersion data in frequency (Hz) and phase velocity (m/s). In addition to three-component passive-source recordings intended for microtremor-based horizontal-vertical spectral-ratio (mHVSR) analyses, an active-source surface linear array-based method consisting of the multi-channel spectral analysis of surface wave (MAS$_\text{R}$W; Rayleigh waves) technique and a passive-source surface nested-circular array-based techniques using microtremor array procedures were performed at station CI.IMP (32.90147, –115.56071) located on "soil" (sedimentary basin) conditions at the Spreckel Sugar Factory (Imperial) property in the Imperial Valley. Figure 6b shows sample Rayleigh-wave dispersion data based on site recordings using the MAS$_\text{R}$W technique.

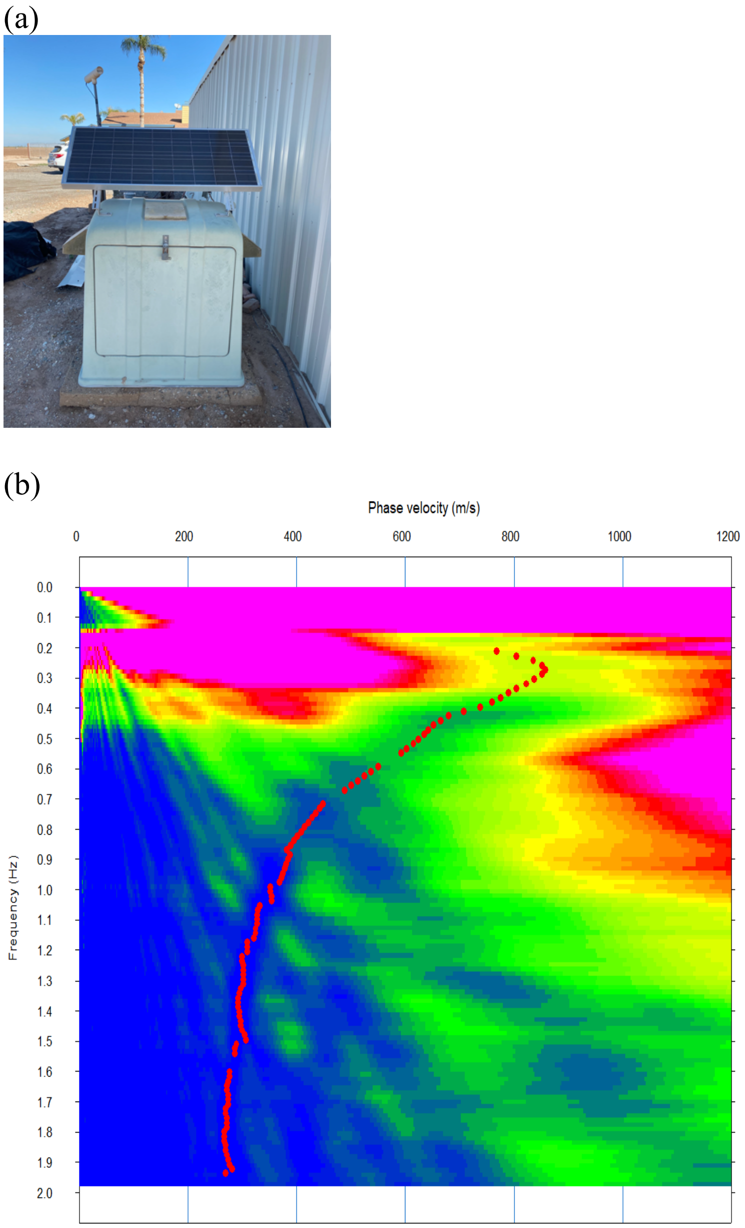

Figure 7. (a) Photo of site conditions at CI.SNR (Photo credit: Jose Gomez); (b) Plot of SPAC dispersion data in frequency (Hz) and phase velocity (m/s); an algorithm-based automatically picked maximum amplitude curve is included. In addition to three-component passive-source recordings intended for microtremor-based horizontal-vertical spectral-ratio (mHVSR) analyses, the active-source surface linear array-based method consisting of the multi-channel spectral analysis of surface wave (MAS$_{R}$W; Rayleigh waves) technique and the passive-source surface nested-circular array-based techniques using microtremor array procedures were also performed at station CI.SNR (32.86189, –115.43595) located on “soil” (sedimentary basin) conditions at the Schaffner Ranch property in the Imperial Valley. Figure 7b shows sample Rayleigh-wave dispersion data based on site recordings using the SPAC technique.

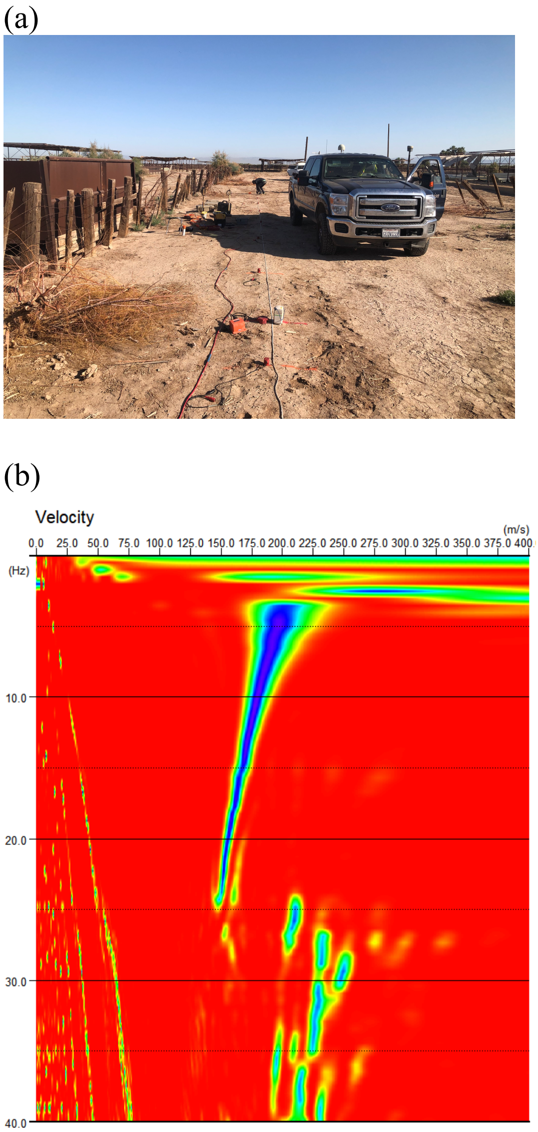

Figure 8. (a) Photo of site conditions at CI.WMD (Photo credit: Jose Gomez); (b) Plot of MAS$_{\text{R}}$W dispersion data in frequency (Hz) and phase velocity (m/s). In addition to three-component passive-source recordings intended for microtremor-based horizontal-vertical spectral-ratio (mHVSR) analyses, the active-source surface linear array-based method consisting of the multi-channel spectral analysis of surface wave (MAS$_{\text{R}}$W; Rayleigh waves) technique and the passive-source surface nested-circular array-based techniques using microtremor array procedures were also performed at station CI.WMD (32.03826, –115.58191) located on “soil” (sedimentary basin) conditions at the San Pasqual Land and Cattle Company (Westmoreland) property in the Imperial Valley. Figure 8b shows sample Rayleigh-wave dispersion data based on site recordings using the MAS$_{\text{R}}$W technique.