Hornsby Bend (HB) Surface Wave Datasets: Metadata

Background Information:

The HB Dataset is an experimental surface wave dataset collected at the Hornsby Bend site in Austin, Texas. This site has been studied extensively over the past few years using both invasive (i.e., SPT borings, CPT soundings, seismic downhole testing, direct-push crosshole testing) and non-invasive (i.e., active and passive surface wave testing, full waveform inversion) methods. The non-invasive testing has been performed using both traditional (e.g., geophones and seismometers) and advanced (e.g., distributed acoustic sensing; DAS) sensor arrays with both simple impact (e.g., sledgehammer) and advanced harmonic (e.g., vibroseis shaker truck) sources. A list of published papers and open-access datasets that document testing at the HB site are provided at the end of this document.

The following active-source MASW and ambient-wavefield MAM arrays will be discussed in this example (refer to Figure 1): **(a) a 94-m long, linear MASW array** of 48, 4.5-Hz vertical geophones spaced at equal intervals of 2m, **(b) a 65-m aperture, triangular MAM array**, and **(c) a 200-m aperture, triangular MAM array**, both composed of seven, thee-component broadband seismometers. Note that active-source surface wave data was also collected using a 200-m long distributed acoustic sensing (DAS) fiber optic cable array. However, this dataset will not be discussed in the present example.

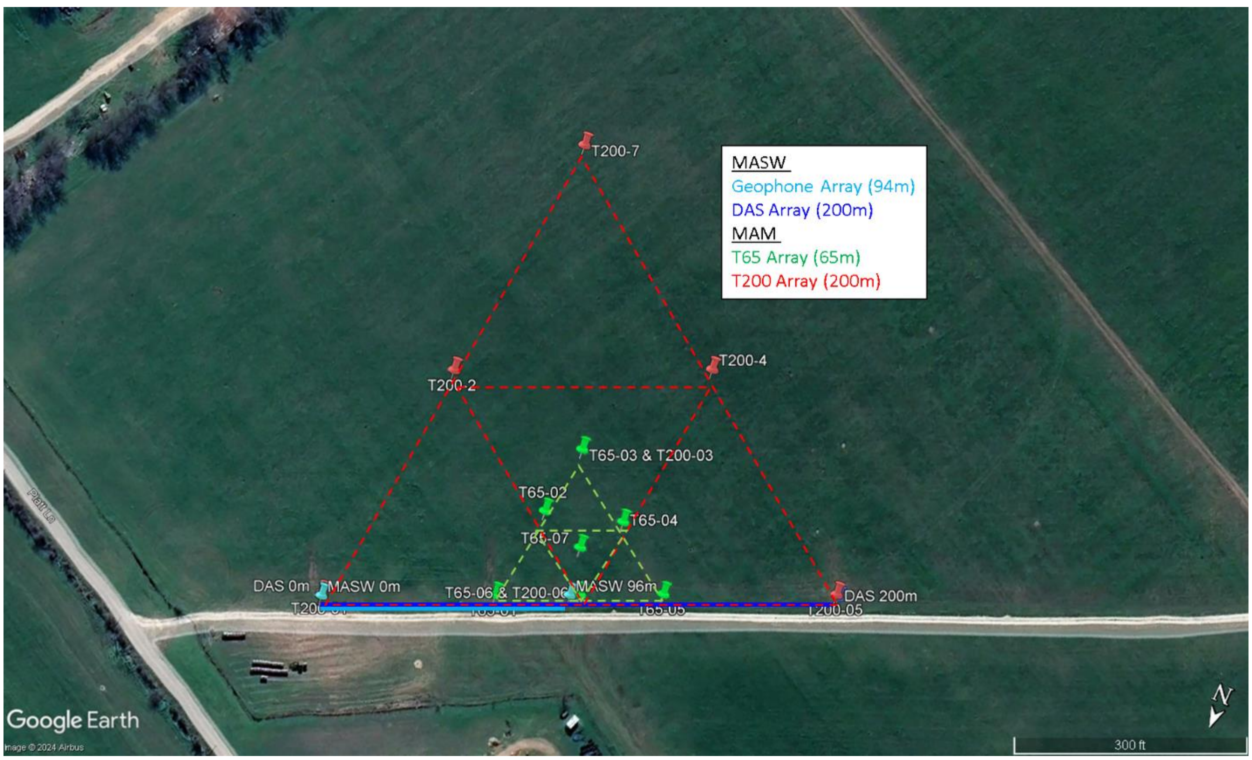

Figure 1: Surface wave testing arrays used at the Hornsby Bend site. The following active-source MASW and ambient-wavefield MAM arrays will be discussed in this example: (a) a 94-m long, linear MASW array of 48, 4.5-Hz vertical geophones spaced at equal intervals of 2m, (b) a 65-m aperture, triangular MAM array, and (c) a 200-m aperture, triangular MAM array, both composed of seven, thee-component broadband seismometers. Note that active-source surface wave data was also collected using a 200-m long distributed acoustic sensing (DAS) fiber optic cable array. However, this dataset will not be discussed in the present example.

(a) Active-source MASW Rayleigh-wave data collected with a 96-m long geophone array

Data Format: Time histories in Seismic Unix (.SU) format. Note that SU format is a modified version of SEG-Y and can be open directly in *swprocess*.
Receivers: 48, vertical, 4.5-Hz geophones (Geospace Technologies GS-11D installed in PC21 land case) coupled to the ground surface (grass) with a 7.6-cm spike. All sensors were spaced at an equal interval of 2 m (total array length of 94 m). The coordinates for the beginning and ending of MASW geophone array are provided in Table 1.
Sources: Three different types of sources were used:

(1) A 5.4-kg (12-lb) sledgehammer impacted vertically downward on an aluminum strike-plate, with five (5) distinct blows recorded individually (not stacked in the field);
(2) The NHERI@UTexas urban shaker truck (vibroseis) named "Thumper" operated in vertical mode (P-wave mode) using a 12-second long linear chirp with frequencies swept from 5 to 200 Hz. Three (3) distinct shots were recorded individually (not stacked in the field);
(3) The NHERI@UTexas large, triaxial shaker truck (vibroseis) named "T-Rex" operated in vertical mode (P-wave mode) using a 12-second long linear chirp with frequencies swept from 3 to 80 Hz. Three (3) distinct shots were recorded individually (not stacked in the field);

Note that for these example datasets, all three sources were positioned at the same four (4) shot locations relative to the first geophone in the array (0m); namely, source-offset distances of -5m, -10m, -20m and -40m were used. Also note that for these example datasets, the source positions were not "reversed" off the far side of the array.
Acquisition System: Two (2) 24-channel Geode seismographs manufactured by Geometrics (24 bit ADC, 144 dB dynamic range, zero hardware gain and 90 dB anti-alias filters). Output units are in seismograph units (i.e., not in engineering units).
Acquisition Parameters: All signals were digitized using a sampling rate of 1ms (1kHz sampling frequency). The sledgehammer impacts were recorded using a 4-second long time window with a 1-second long pre-trigger delay and a 3-second long "listen". The vibroseis chirps were recorded using a 16-second long time window with a 1-second long pre-trigger delay and a 15-second long "listen".
Data file description: Files are named according to the following convention –

Source type_Source direction/mode_Sensor type_Shot Location_Shot number.su

For example, the file named "hammer_p_geo_-5m_0.su" contains the 48 records obtained from the sledgehammer source, operated in p-mode (vertical direction), recorded using geophones, at the -5m shot location, for the first (i.e., "0") shot. Note that the second shot is "1", the third shot is "2", etc.

(b) & (c) Ambient-wavefield MAM data collected with triangular arrays (T65 and T200)

Data Format: Time histories in miniseed (.mseed) format. Note that SEED stands for "Standard for the Exchange of Earthquake Data". These files can be opened directly in Geopsy.
Receivers: Seven (7), three-component, 20-s period (flat response from 100 Hz to 20 seconds), broadband seismometers (Nanometrics, Inc. Trillium Compacts). The receivers were placed in shallow holes, oriented to magnetic north, leveled, coupled to the native ground with compacted soil, and covered with a weighted bucket. The 7 sensors were placed in nested triangular arrays with approximate maximum apertures of 65m and 200m (i.e., the T65 and T200 arrays, respectively). The coordinates for each receiver in each MAM array are provided in Table 2.
Source: Ambient-wavefields (i.e., noise, microtremors, passive-source).
Acquisition System: Nanometrics Inc. Centaur digitizers (24 bit ADC, 141 dB dynamic range and internal clock and GPS receiver accurate to <100 μsec). Outputs units are in counts.
Acquisition Parameters: A 200 Hz sampling rate was used to record 1.5-hour long time records for the T65 array and 3.0-hour long records for the T200 array. Note that there are some short "zero

data"/flat amplitude segments on some of the sensor records near the tops of the hours in absolute UTC time. These zero data segments were caused by digitizer errors when writing the files to disk at the tops of the hours. We have checked for time continuity across these segments and found them to not effect the quality of the data processing.

Data file description: Files are named according to the following convention –

Array name_Station name.mseed

For example, the file named "T65_STN11.mseed" contains the three-component, 1.5-hour long records obtained from the T65 array and the UT_STN11 station. The three components are clearly labeled as "Vertical", "North", and "East" in the .mseed files.

Table 1: Coordinates for the end-points of the linear MASW arrays used at the Hornsby Bend site.

Linear Array	Point	Latitude (deg)	Longitude (deg)
Geophone	0m	30.231939°	-97.636374°
	96m	30.231589°	-97.637290°
DAS	0m	30.231939°	-97.636374°
	200m	30.231217°	-97.638288°

Table 2: Coordinates for the three-component broadband seismometers used for the T65 and T200 MAM arrays at the Hornsby Bend site.

MAM Array	Position Name	Station Name	Latitude (deg)	Longitude (deg)
T65	1	UT_STN11	30.231691°	-97.637016°
	2	UT_STN12	30.231353°	-97.637061°
	3	UT_STN13	30.231105°	-97.637098°
	4	UT_STN14	30.231278°	-97.637367°
	5	UT_STN15	30.231454°	-97.637635°
	6	UT_STN16	30.231572°	-97.637327°
	7	UT_STN17	30.231420°	-97.637250°
T200	1	UT_STN11	30.231931°	-97.636374°
	2	UT_STN12	30.231034°	-97.636497°
	3	UT_STN13	30.231105°	-97.637098°
	4	UT_STN14	30.230667°	-97.637445°
	5	UT_STN15	30.231209°	-97.638279°
	6	UT_STN16	30.231572°	-97.637327°
	7	UT_STN17	30.230135°	-97.636608°

Additional Information:

As noted above, the Hornsby Bend site has been studied extensively over the past few years using both invasive (i.e., SPT borings, CPT soundings, seismic downhole testing, direct-push crosshole testing) and non-invasive (i.e., active and passive surface wave testing, full waveform inversion) methods. A list of some of the more pertinent published papers and open-access datasets that document testing at the HB site are provided below. These papers included comparisons between 1D and 2D non-invasive imaging results and ground truth obtained from SPT borings and CPT soundings.

Peer-reviewed journal publications

1. Yust, M.B.S., Cox, B.R., Vantassel, J.P., Hubbard, P.G. (2024). "DAS for 2D MASW Imaging: A Case Study on the Benefits of Flexible Sub-Array Processing," *Geophysics Journal International* 237 (3) 1609-1623. (https://doi.org/10.1093/gji/ggae122).
2. Yust, M.B.S., Cox, B.R., Vantassel, J.P., Hubbard, P.G., Boehm, C., Krischer, L. (2023). "Near-Surface 2D Imaging via FWI of DAS Data: An Examination on the Impacts of FWI Starting Model," *Geosciences*, 13 (3):63. (https://doi.org/10.3390/geosciences13030063).
3. Vantassel, J.P., Cox, B.R., Hubbard, P.G., Yust, M. (2022). "Extracting High-Resolution, Multi-Mode Surface Wave Dispersion Data from Distributed Acoustic Sensing Measurements using the Multichannel Analysis of Surface Waves," *Journal of Applied Geophysics*, 205 (1): 104776. (https://doi.org/10.1016/j.jappgeo.2022.104776).

Open-access datasets

1. Yust, M., Cox, B.R., Menq, F., Hubbard, P., Vantassel, J. (2023) "Active-Source, Near-Surface, Surface-Wave Measurements using Distributed Acoustic Sensing (DAS), Cone Penetration Testing (CPT), and Downhole (DH) Testing", *in Characterization of the NHERI@UTexas Hornsby Bend Test Site*. DesignSafe-CI. https://doi.org/10.17603/ds2-6ap5-sk09 v2
2. Vantassel, J., Cox, B.R., Hubbard, P., Yust, M., Menq, F. (2022) "Active-Source, Near-Surface, Surface-Wave Measurements using Distributed Acoustic Sensing (DAS) and Traditional Geophones", in *Characterization of the NHERI@UTexas Hornsby Bend Test Site*. DesignSafe-CI. https://doi.org/10.17603/ds2-bz52-ep82.