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Delaney Park Downhole Array in Anchorage, Alaska—Site Properties Inferred from M7 Anchorage, Alaska Earthquake

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Abstract

Delaney Park downhole (DPK) array data from the 2018 M7.0 Anchorage earthquake and its six aftershocks (between M4.2 and 5.7) were used to infer the site properties including:

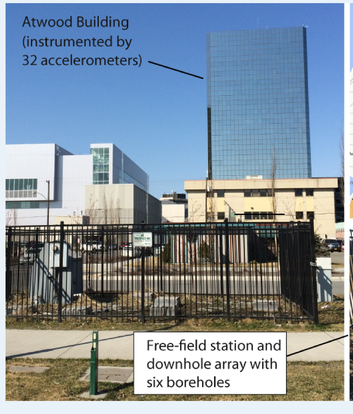
1. predominant site frequencies,
2. shearwave velocity profile, and
3. site amplification.

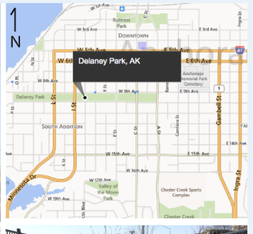
The records at the DPK array were measured by surface instrument and six borehole (up to 61 m depth) three-component accelerometers.

Deconvolution of the waveforms at various depths with respect to the surface waveform provides upward (incident) and downward (reflected) travelling waves within the soil layers.

The site amplification values based on surface-to-downhole traditional spectral ratio (SSR), response spectral ratio (RSR), cross-spectral ratio (c-SSR), and horizontal-to-vertical spectral ratio (HVSR) of the surface recordings were also computed.

The Site

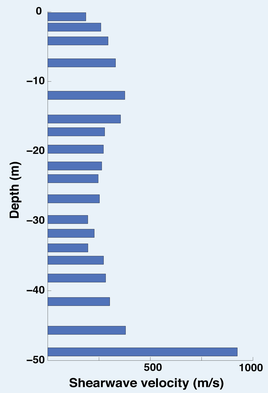




In 2003, USGS established a seven-level downhole array of three-component accelerometers at Delaney Park in downtown Anchorage.

This array was installed to measure sediments response to ground shaking, and to provide input wave-field to nearby 20-story steel building (Atwood Building), also instrumented.

Geology & Instrumentation

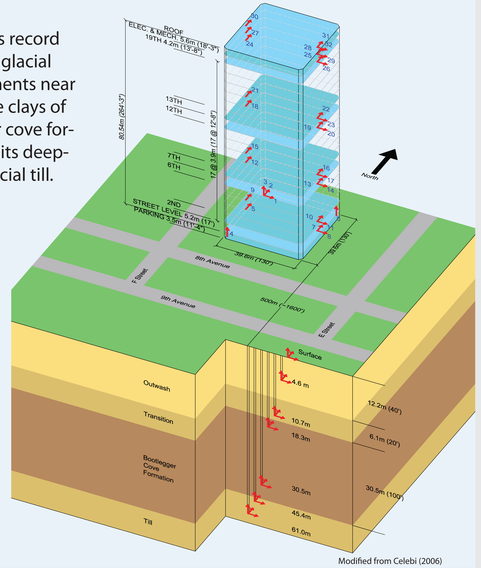


The geological section at the site consists of silty materials including outwash, bootlegger cove foundation and till deposited in a late Pleistocene glaciomarine-glaciodeltaic environment (Ulery et al., 1983).

The bootlegger cove foundation (from 20-50 m) is a soft formation thought to be responsible for much of the liquefactiondamage during the 1964 earthquake.

Shearwave velocity with depth based on geophysical measurements at a site about 200 m away from the DPK. Shear-wave velocity is lower between -20 and -48 m at Bootlegger Cove formation than the shallower glacial outwash (between 0 and -12.2 m) (see also Figure below for geological profile) (adapted from Nath et al., 1997 and Yang et al., 2008).

Accelerometers record motions in the glacial outwash sediments near the surface, the clays of the bootlegger cove formation, and at its deepest into the glacial till.



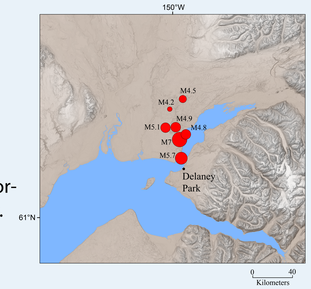
Modified from Celebi (2006)

Data

A magnitude 7 earthquake struck Anchorage, Alaska on November 30, 2018. Six aftershocks with magnitudes above 4 were recorded on the same day.

The largest PGA of 0.24 g was recorded at DPK during the mainshock.

The M5.7 event is the cloest aftershock with a PGA of 0.04 g.



Event	Date (y-m-d)	Magnitude	Epicenter Coordinates		Depth (km)	Distance (km)	PGA (cm/s²)
			Lat. (°)	Long. (°)			
1	2018/11/30	7	61.340	-149.937	40	14.3	233.8
2	2018/11/30	4.8	61.363	-149.880	44	16.7	41.4
3	2018/11/30	5.7	61.259	-149.921	39	5.3	41.4
4	2018/11/30	4.5	61.516	-149.908	41	33.7	8.7
5	2018/11/30	4.9	61.394	-149.972	38	20.5	13.3
6	2018/11/30	5.1	61.392	-150.064	31	21.9	17.5
7	2018/11/30	4.2	61.472	-150.026	21	29.6	2.9

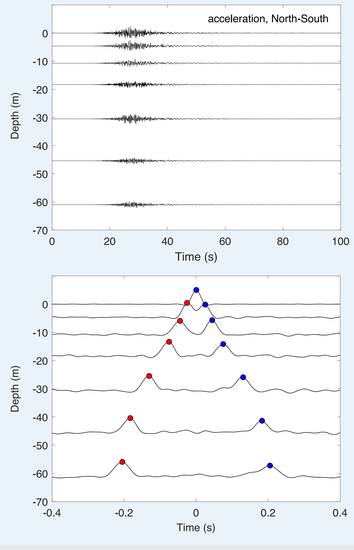
Wave Propagation

The soil responses from six boreholes were deconvolved by the soil response measured at the surface.

The deconvolved waveforms demonstrate a wave state of the borehole array as if the motion at the surface was given by a delta function (Snieder and Safak, 2006).

For early times, this pulse travels downward in the soil column with a velocity equal to shear wave velocity of soil layers. At t = 0, the wave field is non-zero only at the surface.

The deconvolved waves are acasual (no phase shift).



Shearwave Velocity

Average shearwave velocity of the upper 61 m of the soil is estimated from the shearwave velocities of the five layers.

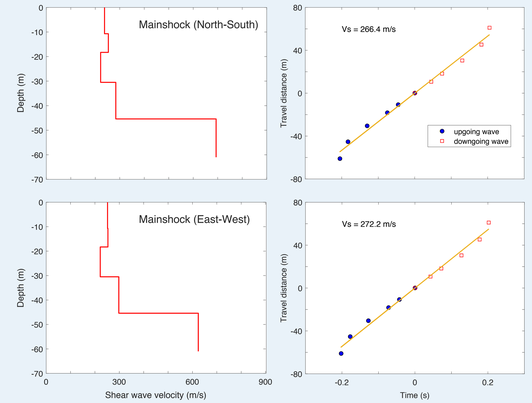


Figure (left) shows estimated shearwave velocity profiles. Figure (right) displays the arrival time and travel distance of the upward and downward travelling waves. A straight line is fitted to estimate an average shearwave velocity.

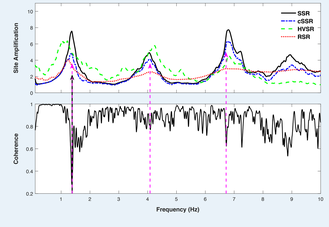
Estimated average shearwave velocity for mainshock and aftershocks:

Direction	Event							Median
	1	2	3	4	5	6	7	
East-west	272.2	283.7	286.4	291.2	292.6	289.1	294.5	287.1
North–south	266.4	281.6	284.4	291.1	288.1	289.6	293.0	284.9

Site Amplification and Predominant Frequencies

Site amplification was estimated as 4.8 at 1.35 Hz (0.74 s), close to the predominant frequency.

The frequencies of the first four modes of the soil column were also identified.



Take-home Message

- Estimated shearwave velocity profile matches with in-situ measurements.
- Site amplifcation is also close to average value reported in and around Anchorage by previous studies (Nath et al., 2002; Martirosyan et al., 2002; Dutta et al., 2003).