Ambient Vibration and Earthquake Strong-Motion Data Sets for Selected USGS Extensively Instrumented Buildings

By François Dunand[1], Janise E. Rodgers[2], Arnold V. Acosta[2], Marion Salsman[2], Pierre-Yves Bard[1], and Mehmet Çelebi[2]

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[1] Laboratorie de Geophysique Interne et Tectonophysique (LGIT), Grenoble, France
[2] U.S. Geological Survey, Menlo Park, California

Table of Contents

List of Figures

List of Tables

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[2] U.S. Geological Survey, Menlo Park, California, USA

Introduction

The objective of this report is to present background information for a study comparing the dynamic characteristics of thirteen buildings obtained using strong-motion and ambient vibration records. Ambient vibration testing is an attractive method of measuring the dynamic characteristics of real buildings, since it does not disrupt building occupants and the necessary equipment is small, light, and very portable. However, because of the low amplitude range of the ambient vibration (10^{-5}g), dynamic characteristics obtained from ambient vibration should be different from those obtained from strong-motion (>0.1 g) records due to non-linear effects (Çelebi 1993, Çelebi 1998).

The strong motion records were provided by the U.S. Geological Survey (USGS) National Strong-Motion Program (NSMP). At least one strong-motion record is available and has been processed for each building, and as many as sixteen seismic records are available for some buildings. Ambient vibration records were collected using velocimeters (velocity transducers). In order to test the efficiency of the ambient vibration for defining the dynamic parameters of structure, a set of three permanently instrumented buildings has been monitored using ambient vibration.

This report describes (1) the 13 buildings with their permanent instrumentation and locations where ambient data was recorded, (2) the ambient vibration testing, and (3) a description of the strong-motion data sets available for each building. This report contains background information only; no results are presented.

Building Descriptions

The buildings selected for this study meet three criteria: (1) they are located in either the greater Los Angeles or San Francisco Bay areas; (2) they are extensively instrumented by the USGS; and (3) they have been strongly shaken by earthquakes with peak ground accelerations in excess of 10% of the acceleration of gravity. Study buildings are listed in Table 1.

Table 1. Buildings included in study

NSMP Station	Building Name	City	Stories	Structural System
482	LA County Public Works Headquarters	Alhambra	13	Steel moment frame
804	Whittier Lutheran Towers	Whittier	10	Reinforced concrete moment frame
1103	Former Great Western Savings	Berkeley	13	Proprietary lift-slab
1225	San Francisco VA Hospital	San Francisco	6	Reinforced concrete shear wall
1226	Livermore VA Hospital	Livermore	6	Reinforced concrete shear wall
1239	Transamerica Pyramid	San Francisco	49	Steel moment frame
1662	Pacific Park Plaza	Emeryville	30	Reinforced concrete moment frame
5106	Long Beach VA Hospital	Long Beach	11	Base isolation retrofit w/shear walls
5229	Loma Linda VA Hospital	Loma Linda	4	Reinforced concrete shear wall
5239	Imperial Norwalk Centre	Norwalk	7	Steel moment frame
5245	San Bernardino County Services Building	San Bernardino		Steel moment frame/braced frame dual system
5281	Brinderson Towers #2	Irvine	13	Steel moment frame
5407	Millikan Library	Pasadena	9	Reinforced concrete shear wall

A brief description of building characteristics, photographs, and a schematic showing the locations of permanent instrumentation are provided for each building. Instrument placements for ambient vibration tests made using velocimeters (if performed) are shown relative to the permanent instrumentation. Floor levels where either permanent instruments are deployed or ambient vibration tests were performed are shown in blue on the schematics. Permanent accelerometer locations and directions are indicated by red arrows, and locations where ambient vibration measurements were taken are shown by green cylinders.

Station 482 – Los Angeles County Public Works Headquarters

900 South Fremont Street, Alhambra

The thirteen-story Los Angeles County Public Works Headquarters, shown in Figure 1, was constructed in 1970. The structural system consists of large reinforced concrete piers and shear walls up to the second floor, with a steel moment frame with pre-Northridge connections above the second floor. Instrumentation configurations for the building are shown in Figure 2. The building was initially instrumented in 1971 with code-mandated tri-axial Kinemetrics SMA-1[*] analog accelerographs at the basement, 6^{th} floor, and 12^{th} floor. The instrumentation system was changed in 1989 to a structural array with three independent horizontal accelerometers at the 2^{nd}, 6^{th}, and 12^{th} floors, and a tri-axial accelerometer in the basement. Both torsional and translational accelerations can be measured at the 2^{nd}, 6^{th}, and 12^{th} floors. An extensive set of strong-motion data is available and contains records from 1971 to present.

Figure 1. 900 S. Fremont St. exterior (left) and strong-motion and ambient testing instrument setup (right) (photos by Janise Rodgers)

[1*] Use of trade, firm, or product names does not imply endorsement by the U.S. Government or the authors.

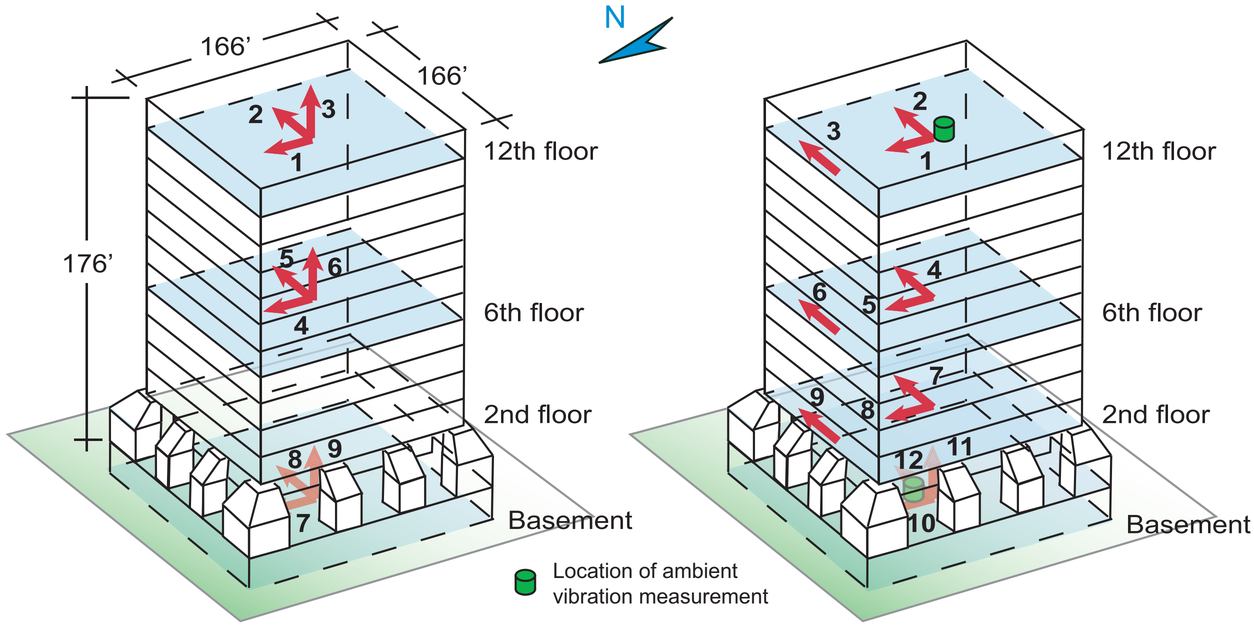


Figure 2. Instrumentation schemes and ambient vibration measurement locations for 900 S. Fremont St.: code instrumentation 1971-1989 (left) and extensive instrumentation 1989-present (right). Instrumented floors are blue, accelerometer locations are marked by red arrows, and ambient vibration measurement locations are marked by green cylinders.

Station 804 – Whittier Lutheran Towers

7215 Bright Avenue, Whittier

The ten-story Whittier Lutheran Towers building, shown in Figure 3, was designed in 1973. The structural system consists of a ductile reinforced concrete moment frame with shear walls. The building's instrumentation, shown in Figure 4, consists of three tri-axial Kinemetrics SMA-1* analog accelerographs at the basement, 5th, and 10th floors. A number of earthquakes, most notably the nearby 1987 Whittier Narrows quake and several large aftershocks, have been recorded by the instrumentation system.

Figure 3. Exterior view of 7215 Bright. Ave. (photo by Janise Rodgers)

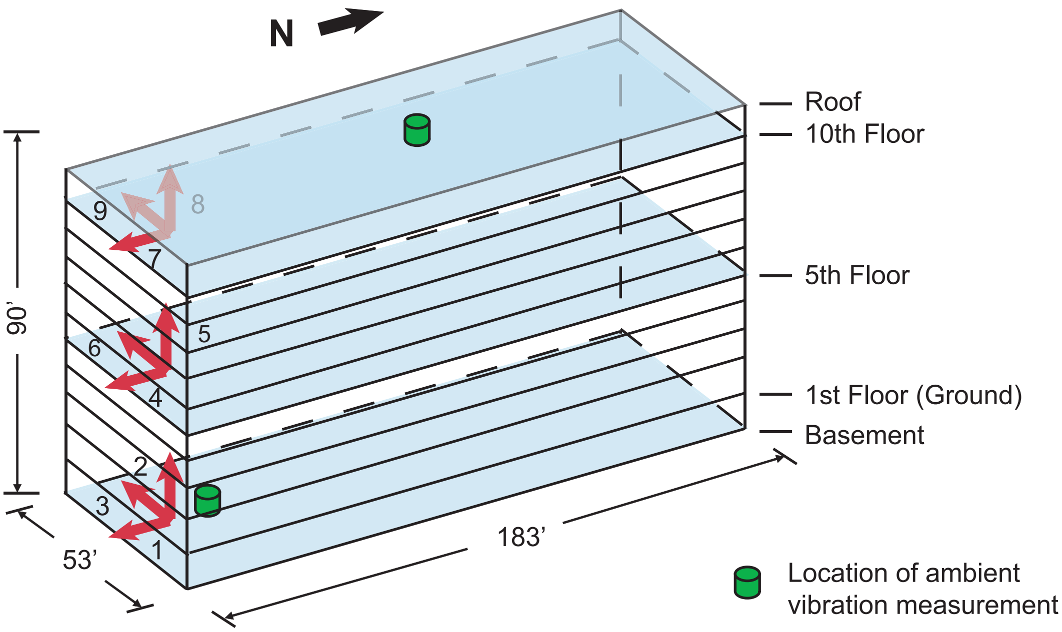


Figure 4. Instrumentation scheme and ambient vibration measurement locations for 7215 Bright Ave.

* Use of trade, firm, or product names does not imply endorsement by the U.S. Government or the authors.

Station 1103 – Former Great Western Savings Building

2150 Shattuck Avenue, Berkeley

The former Great Western Savings building, now adorned with a large “Powerbar” sign and accordingly dubbed the Powerbar building, was constructed in 1969. The fourteen-story building, shown in Figure 5, was constructed using an proprietary lift-slab structural system, with floors poured at the base of two concrete towers and then jacked into place. Due to the building’s proximity to the Hayward Fault (1.5 km), it underwent a limited-scope, voluntary retrofit in 2000 described in Mar et al. (2000) following a vulnerability assessment. The building’s current instrumentation scheme and ambient vibration measurement locations are shown in Figure 6. The instrumentation configuration differs slightly from that in place at the time of the 1989 Loma Prieta earthquake. Channels 10 and 11 were removed from service during a recent asbestos abatement program and have yet to be reinstalled.

Figure 5. Exterior view of 2150 Shattuck Ave. (photo by Arnold Acosta)

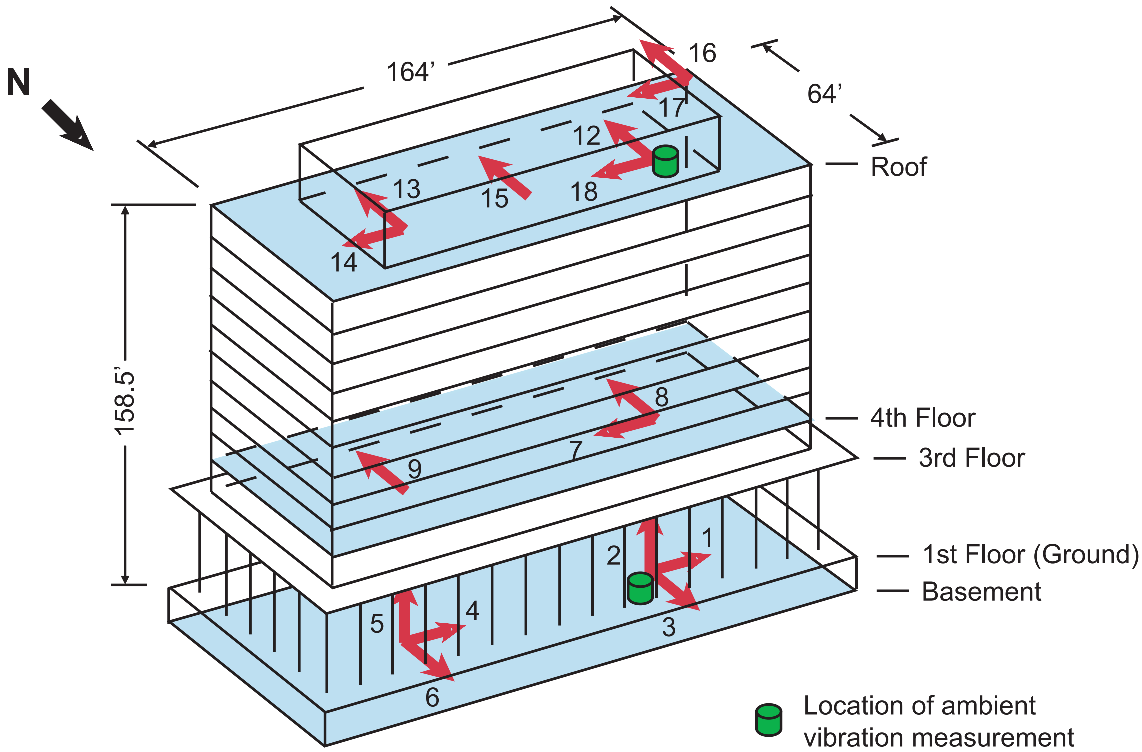


Figure 6. Instrumentation scheme and ambient vibration measurement locations for 2150 Shattuck Ave. (channels 10 and 11 not currently in service)

Station 1225 – San Francisco VA Hospital, Building 2

4150 Clement Street, San Francisco

Main Building Two of the Veterans Administration (VA) Hospital in San Francisco was constructed in the early 1930s. This seven-story C-shaped structure, shown in Figure 7, now forms the 'backbone' of the hospital's nine irregular, interconnected buildings, which are laid out roughly in a delta-wing shape. The lateral force-resisting system consists of nonductile reinforced concrete frames and walls. A remodel and seismic upgrade were performed in 1988-89 before the M6.9 1989 Loma Prieta earthquake. The instrumentation and ambient vibration measurement locations are shown in Figure 8. Permanent instrumentation at the time of the Loma Prieta earthquake consisted of two tri-axial analog accelerographs, which have recently been replaced by tri-axial digital instruments.

Figure 7. Exterior view of 4150 Clement St., Building 2 (photo by François Dunand)

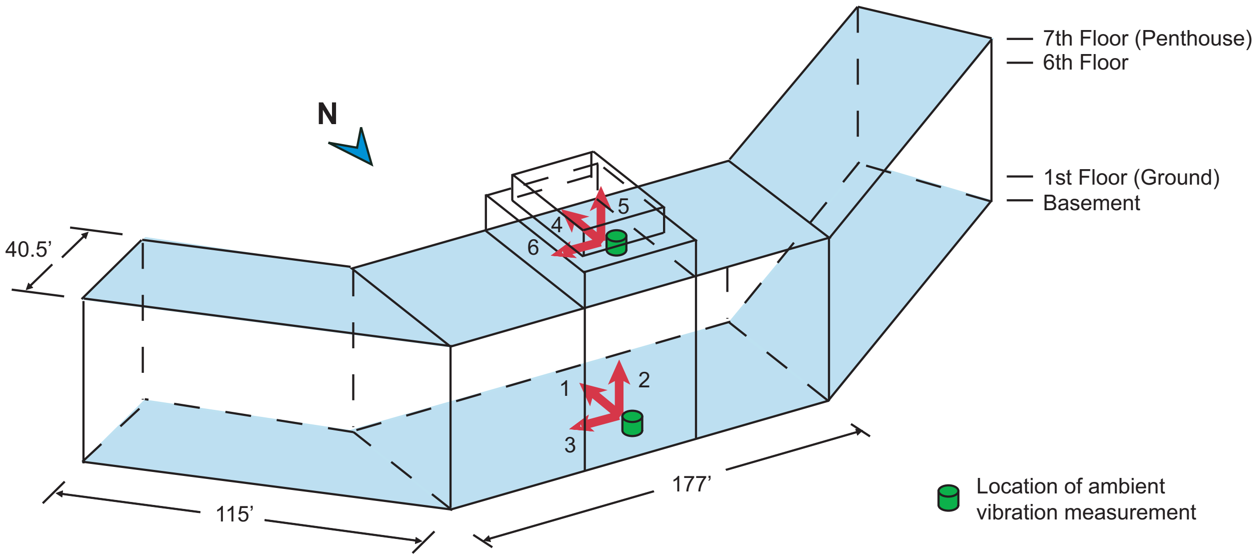


Figure 8. Instrumentation scheme and ambient vibration measurement locations for 4150 Clement St.

Station 1226 – Livermore VA Hospital

4951 Arroyo Road, Livermore

The seven-story Livermore VA Hospital, shown in Figure 9, was constructed between 1947 and 1955. The building is T-shaped and has a lateral force-resisting system consisting of reinforced concrete walls and framing. The building has had some seismic strengthening, also with reinforced concrete, but the extent is presently unknown. The instrumentation and ambient vibration measurement locations are shown in Figure 10. These analog instruments recorded the 1989 Loma Prieta earthquake and several smaller local events.

Figure 9. Exterior view of 4951 Arroyo Rd. (photo by François Dunand)

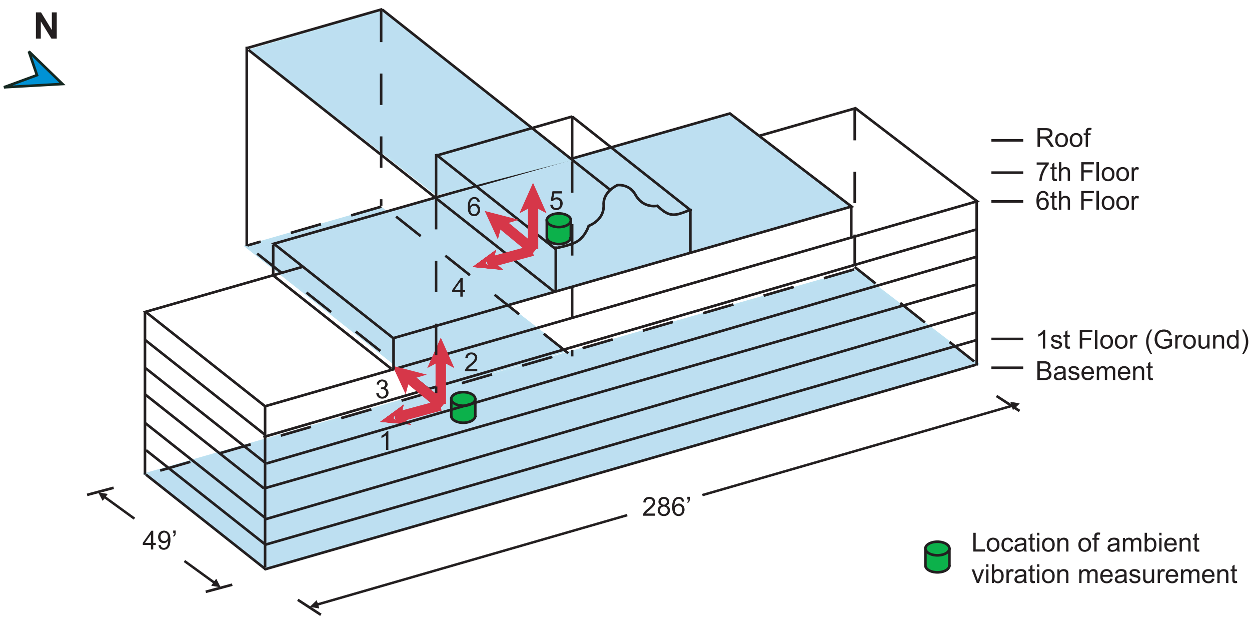


Figure 10. Instrumentation scheme and ambient vibration measurement locations for 4951 Arroyo Rd.

Station 1239 – Transamerica Pyramid

600 Montgomery Street, San Francisco

The Transamerica Pyramid, shown in Figure 11, has been one of the tallest and most recognizable of San Francisco's buildings since its construction in 1972. The building has 48 stories above ground, plus a spire, which brings its total height to over 850 feet. Its lateral force-resisting system consists of steel moment frames which slowly step back to accommodate the sloped exterior walls. The building is extensively instrumented as shown in Figure 12, and its instruments recorded the 1989 Loma Prieta earthquake. The building's accelerometers are now connected to a real-time monitoring system which streams data to a limited number of clients via secure internet connection. Ambient vibration data was acquired using this real-time system; no ambient velocity data was taken.

Figure 11. Exterior view of 600 Montgomery St. (photo by Dan Radulescu)

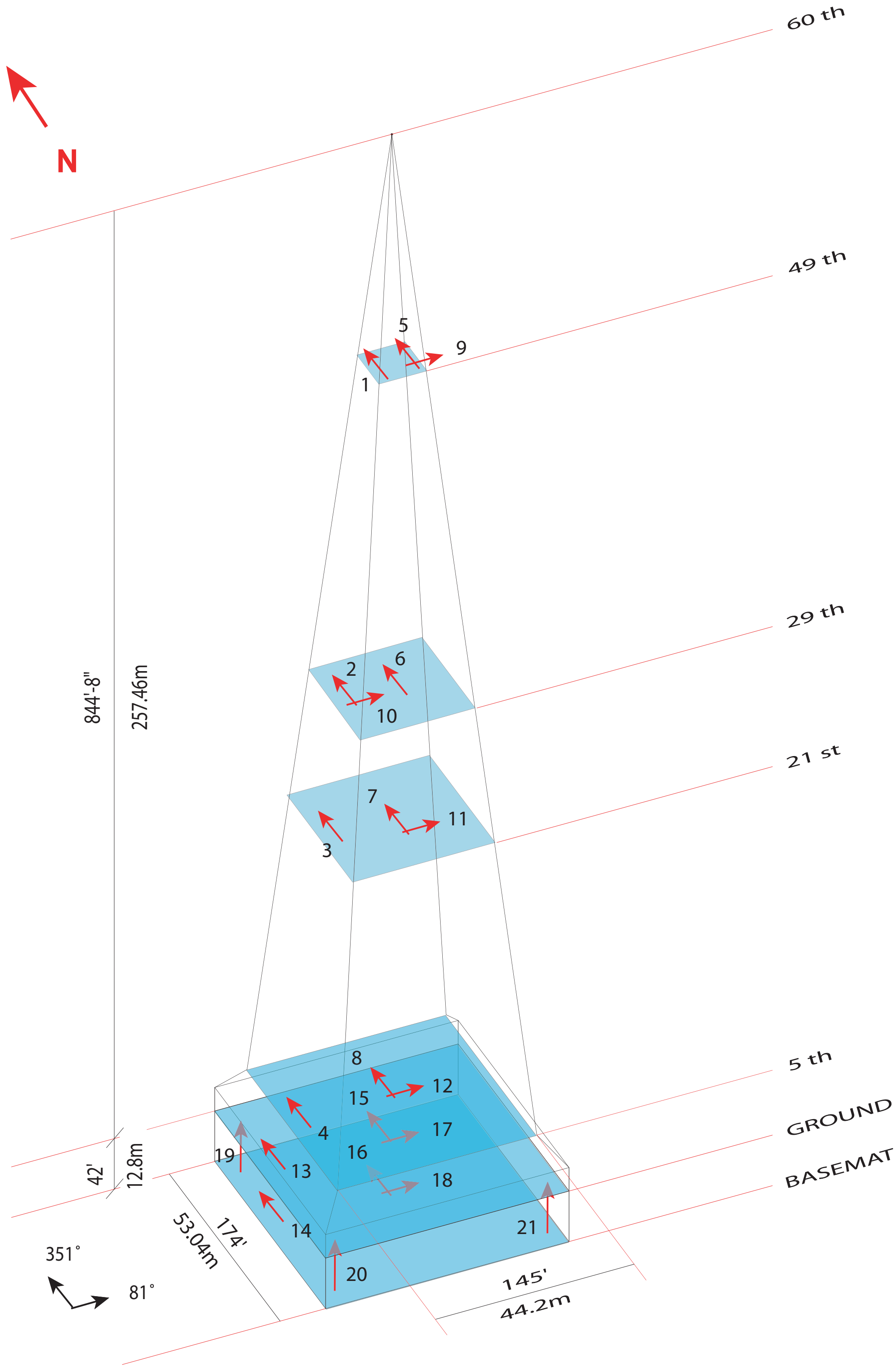


Figure 12. Instrumentation scheme for 600 Montgomery St. Lower floor channels are: 14, 15, 18, 19, 20, 21 atop basemat, 13, 15, 17 at ground level, and 4, 8, 12 at 5^{th} floor.

Station 1662 – Pacific Park Plaza

6363 Christie Avenue, Emeryville

The thirty-story Pacific Park Plaza building in Emeryville, shown in Figure 13, was constructed in 1984. The lateral force resisting system is a ductile concrete moment-resisting frame. The building has a delta wing plan (i.e. three wings equidistant at 120 degrees) and several re-entrant corners at the wing ends. There is a thin layer of young Bay Mud underlying the site. The building was extensively instrumented by the USGS with sensors configured as shown in Figure 14. The structural array is complemented by free-field and downhole instruments. The structural array and free-field instruments recorded the 1989 Loma Prieta earthquake on analog recorders, but all recorders at the site have since been replaced with digital ones.

Figure 13. Exterior view of 6363 Christie Ave. with adjacent reinforced concrete parking garage in foreground (photo by Kent Fogleman).

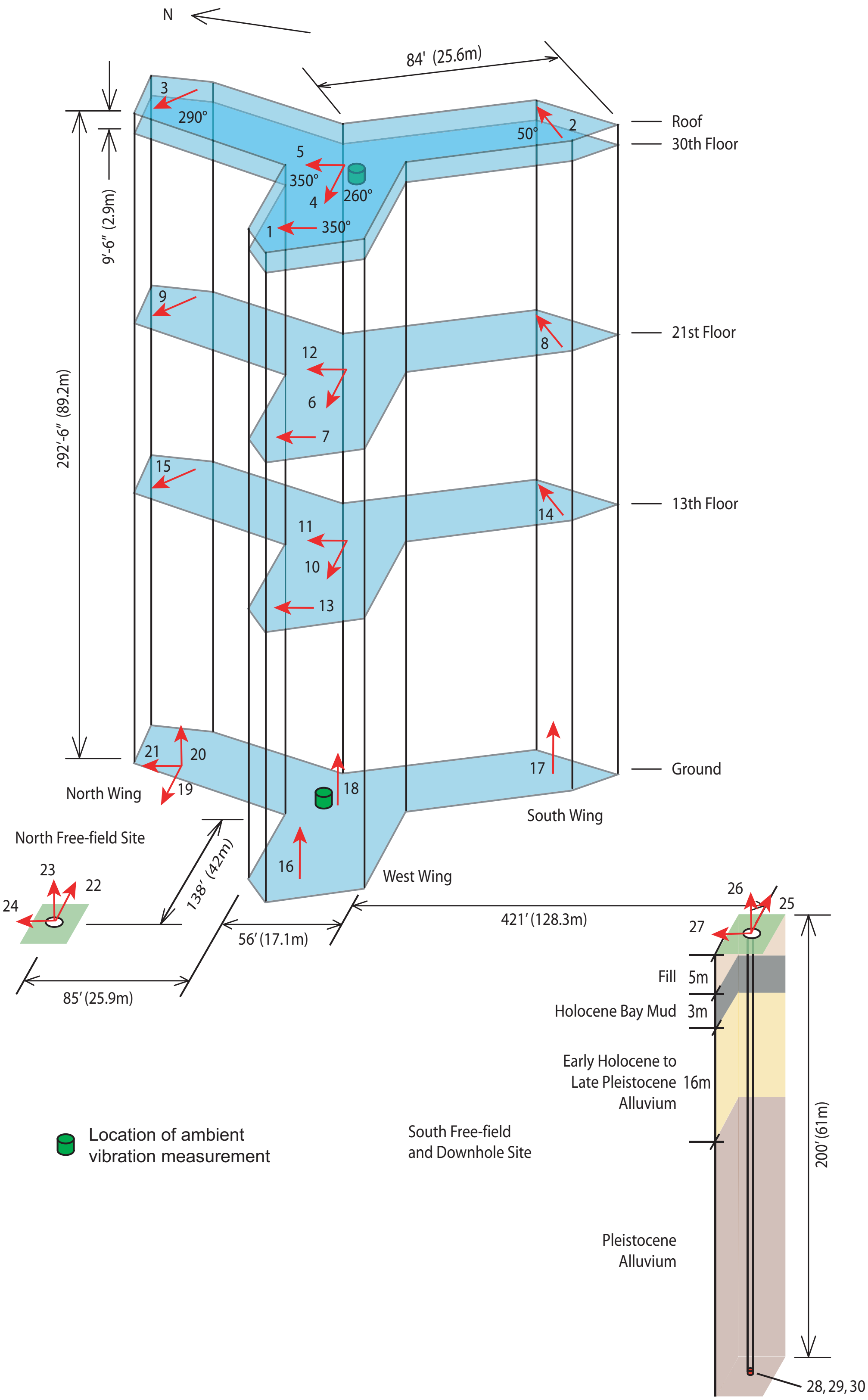


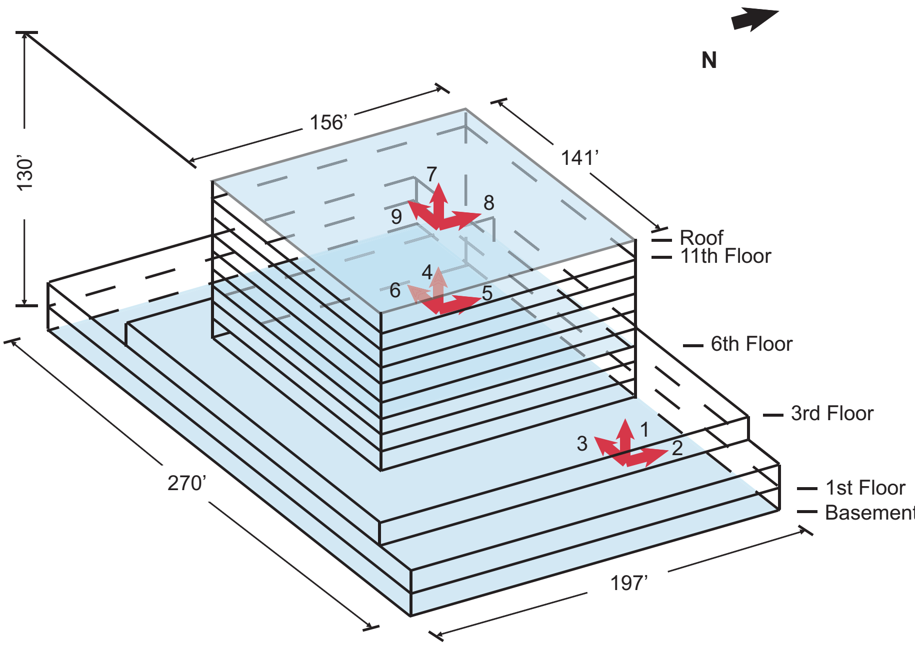
Figure 14. Instrumentation scheme and ambient vibration measurement locations for 6363 Christie Ave. Ambient velocity measurements taken on 30th floor while permanent instruments are located on roof.

Station 5106 – Long Beach VA Hospital

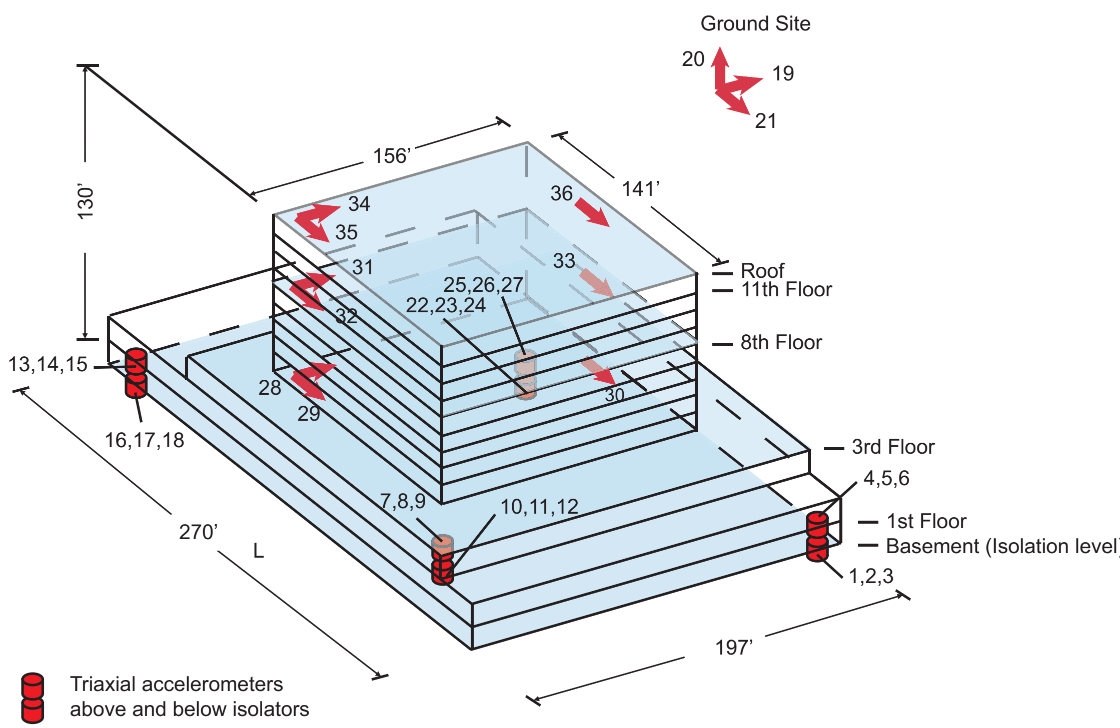
5901 East 7th Street, Long Beach

The Long Beach VA Hospital, shown in Figure 15, is an 11-story non-ductile concrete structure constructed in the 1960s. The building was damaged in the M6.7 1994 Northridge earthquake and subsequently retrofitted with base isolation. The building's instrumentation scheme both before and after the retrofit are shown in Figure 16. The pre-retrofit scheme consisted of tri-axial analog instruments, which were replaced with a modern digital structural array following the retrofit. Several significant earthquakes were recorded prior to the retrofit, but no sizable earthquakes have been recorded since. Ambient vibration data was acquired using the permanent instrumentation system; no ambient velocity data was taken.

Figure 15. Exterior view of 5901 E. 7th St. (photo by Arnold Acosta)



Before Retrofit



After Retrofit

Figure 16. Instrumentation scheme for 5901 E. 7th St., showing configurations before (left) and after (right) seismic retrofit

Station 5229 – Loma Linda VA Hospital

11201 Benton Street, Loma Linda

The Loma Linda Veterans Administration hospital, shown in Figure 17, is a very large building which was constructed in the late 1970s. The structure has many reentrant corners, though no setbacks. The lateral force-resisting system consists of reinforced concrete shear walls. The building is situated in the vicinity of the San Jacinto fault zone. The building's current instrumentation configuration is shown in Figure 18. Currently, only the digital tri-axial instrument in the basement is being maintained, but this situation may improve soon. A number of earthquakes have been recorded by the analog structural array in the building, and a moderately sized strong-motion data set is available.

Figure 17. Wide-angle (left) and close-up (right) exterior views of 11201 Benton St. (photos by Janise Rodgers and François Dunand)

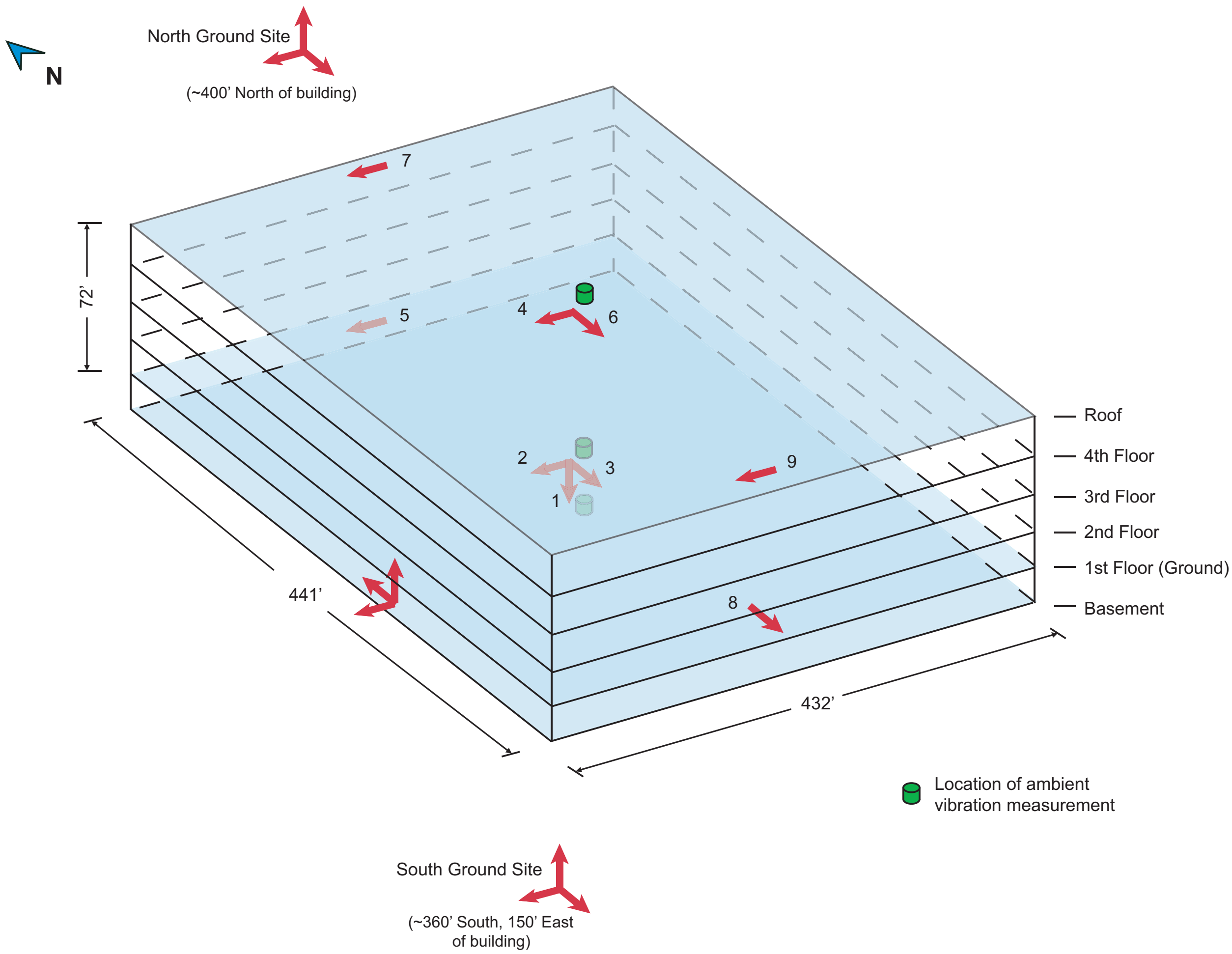


Figure 18. Instrumentation scheme and ambient vibration measurement locations for 11201 Benton St. Accelerometer channel numbers are 1-3, 5, 8 on the 1st floor, and 4, 6, 7, 9 on the roof. A new digital tri-axial package is in the basement. Ambient vibration measurements were taken at the basement, 1st floor and roof.

Station 5239 – Imperial Norwalk Centre

12440 Imperial Highway, Norwalk

The former Bechtel office building at 12440 Imperial Highway in Norwalk is now occupied by a number of local and federal law enforcement agencies. A current photograph of the building is not available. The building is a 7-story steel moment-framed structure constructed in the early 1980's. The building has an unusually high aspect ratio (>3:1) in plan, but no significant vertical or plan irregularities. The building is extensively instrumented with sensors in the configuration shown in Figure 19. The analog structural array has recorded a number of Southern California earthquakes, including the 1987 Whittier Narrows and 1994 Northridge quakes.

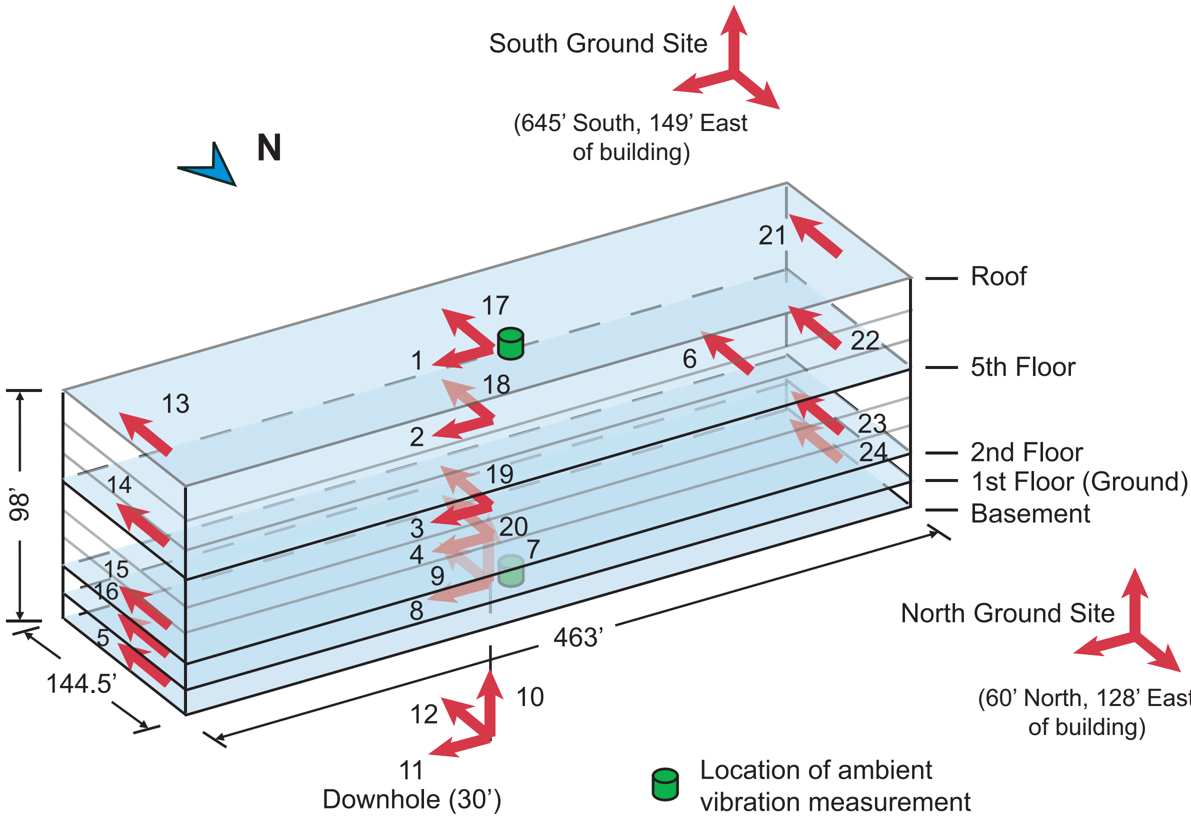


Figure 19. Instrumentation scheme and ambient vibration measurement locations for 12440 Imperial Hwy. Accelerometer channel numbers: 10-12 downhole; 5, 7-9 at basement; 4, 16, 20, 24 on 1st floor; 3, 15, 19, 23 on 2nd floor; 2, 6, 14, 18, 22 on 6th floor, 1, 13, 17, 18, 21 at roof.

Station 5245 – San Bernardino County Services Building

345 North Arrowhead Avenue, San Bernardino

The five-story San Bernardino County Services Building was constructed in 1984. The building's structural system is a dual system with steel moment-resisting frames in the N-S direction and steel concentrically braced frames in the E-W direction. As shown in Figure 20, the building's geometry is basically L-shaped but very irregular, with numerous setbacks and re-entrant corners. Instrumentation consists of a 12-channel structural array and a separate tri-axial instrument in a basement mechanical room on the building's south side. Analog recorders were installed in 1987, and upgraded to digital recorders in 2002.

Figure 20. Front (left) and rear (right) exterior views of 345 N. Arrowhead Ave. (photos by Janise Rodgers and François Dunand)

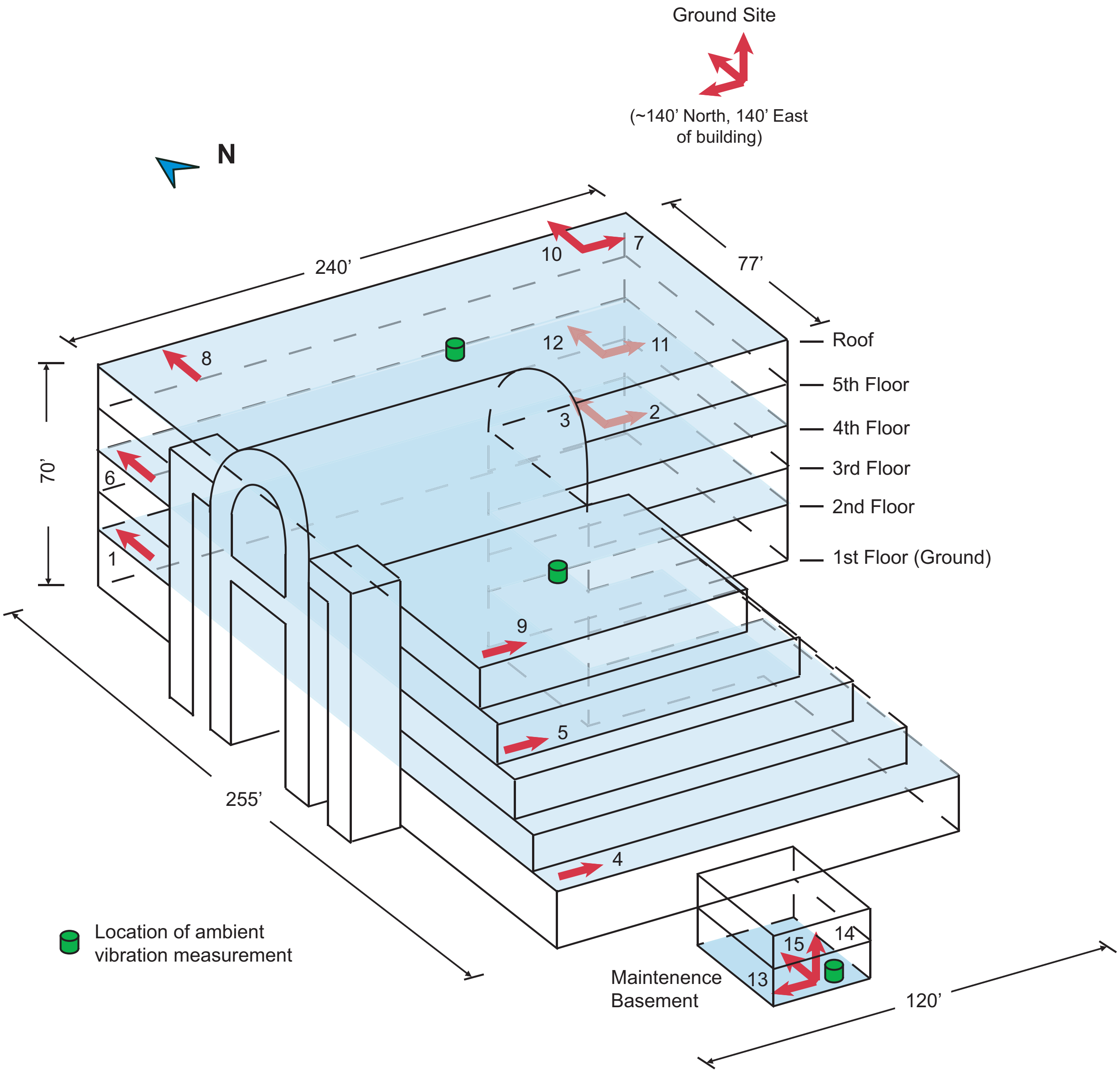


Figure 21. Instrumentation scheme and ambient vibration measurement locations for 345 N. Arrowhead Ave. Ambient velocity measurements were taken at two locations on the roof and at one in the maintenance basement.

Station 5281- Brinderson Towers #2

19900 MacArthur Boulevard, Irvine

The 13-story Brinderson Towers are two nominally identical buildings which were constructed in the period from 1988 to 1992. The lateral force-resisting system of both buildings is a dual steel moment frame / eccentrically braced frame system. Both buildings have a notch in one corner at the base, as shown in Figure 22. The buildings are very regular otherwise. Tower 2 was instrumented with a 12-channel structural array in 1990 by the USGS. Several earthquakes, including the 1992 Landers and 1994 Northridge earthquakes, have been recorded by the structural array, and a small strong-motion data set is available.

Figure 22. Exterior view of 19900 MacArthur Blvd., Tower 2 (photo by Janise Rodgers)

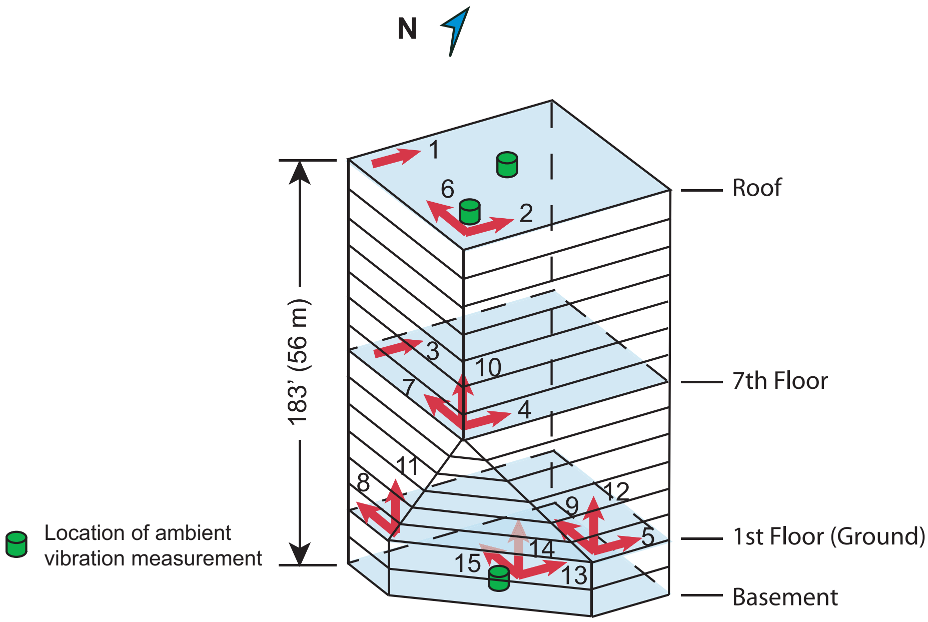


Figure 23. Instrumentation scheme and ambient vibration measurement locations for 19900 MacArthur Blvd.

Station 5407 – Millikan Library

California Institute of Technology campus, Pasadena

Caltech's nine-story Millikan Library, shown in Figure 24, is one of the most extensively-studied buildings in the world. The building was constructed in 1966-67, and has recorded the building's response to a large number of earthquakes. An eccentric mass shaker is located on the roof, and numerous forced-vibration experiments have been conducted. The building's lateral force-resisting system consists of reinforced concrete shear walls in both directions. Early instrumentation consisted of tri-axial analog accelerometers at the basement and roof. The instrumentation was subsequently upgraded to the digital scheme shown in Figure 25, and there are now instruments on every floor, which are connected to both standard digital recorders and a web-based real-time monitoring system.

Figure 24. Exterior view of Millikan Library (photo by François Dunand)

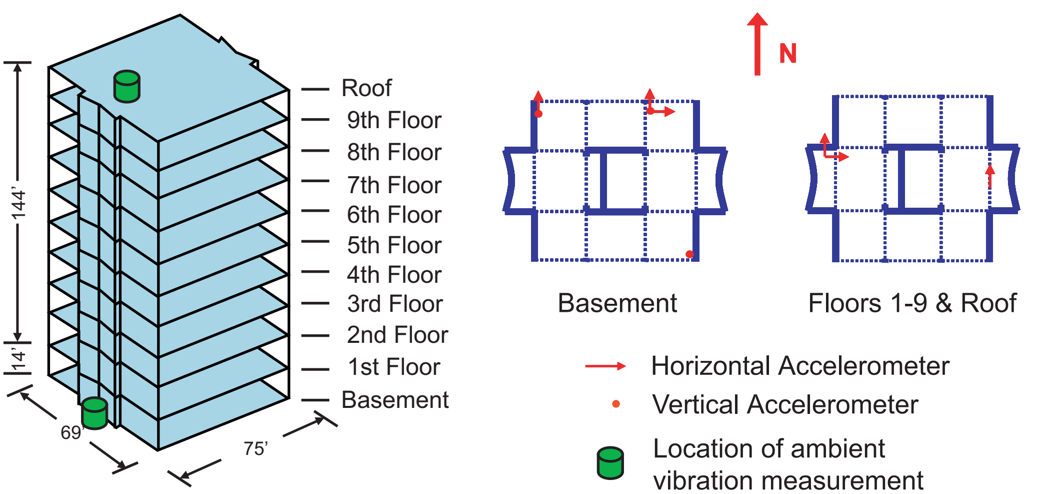


Figure 25. Instrumentation scheme and ambient vibration measurement locations for Millikan Library

Ambient vibration testing

Equipment

The ambient vibration tests carried out on each building were performed with vibration measurement equipment comprising two CityShark^{TM*} acquisition systems, each connected to one velocimeter (velocity transducer) as shown in Figure 26. The CityShark^{TM*} system was developed for specifically for ambient vibration measurements (Chatelain et al. 2000). The analog/digital conversion processor is 24-bit. The sampling frequency can be chosen from five values between 50 samples per second (sps) and 250 sps. The gain can be set between 1 and 16384. The duration of recording can be set at any value between 1 and 60 minutes. This system is portable with its own battery and does not need a PC to run. The data are stored on a flashcard. The velocimeters are Lennartz LE-3D* with 3 components and a weight of 1.8 Kg. The natural (eigen) frequency is 1 Hz and the upper corner frequency is more than 80 Hz.

Figure 26. The CityShark* recorder and the Lennartz LE-3D* velocimeter

Procedure

The following testing procedure was adopted was to obtain data suitable for computing the transfer function of the buildings. Ambient vibrations were recorded at the top and at the bottom of each tested building using the velocimeter test setup described in the previous section. These records were generally not taken simultaneously, but typically either overlapped or were taken consecutively. The velocimeters were located as close as possible to a permanent accelerometer. The records were 30 minutes long with a sampling frequency of 200 Hz. The gain was adjusted to obtain the best amplified record on the horizontal component without clipping.

In the case of the Transamerica Pyramid and the Long Beach VA Hospital, on-site ambient vibration testing using velocimeters was not performed due to logistical constraints. Ambient data for these buildings were obtained from accelerometers in the permanent structural arrays, and were obtained simultaneously at all channels. In addition, ambient vibrations were recorded on both velocimeters and permanent accelerometers for comparison purposes at three buildings with different structural systems.

* Use of trade, firm, or product names does not imply endorsement by the U.S. Government or the authors.

Data

The locations and orientations of the velocimeters are summarized in Table 2. The indicated orientation is the local north azimuth for the velocimeter. The last column shows whether or not ambient vibrations were recorded using the permanent accelerometers in the structural array. Data listed in the table are available from the USGS National Strong Motion Program (NSMP) website (http://nsmp.wr.usgs.gov).

The CityShark* files are made of a header with record information, followed by three columns corresponding to the vertical, local north and local east components of the ambient motion. The units of theses columns are counts and the conversion procedure is:
To obtain Volts : multiply by 2500000.0/32767.0 and divide by the Gain (see header)
To obtain 10^{-6} m/s : divide the volts by 400.0 for the velocimeter Lennartz LE-3D*

Table 2. Location of ambient vibration records

NSMP Station	Building Name	Story	Location	Sensor N Azm (deg)	Near Instrumt.	CityShark* Filename	Ambient Acc Data
482	LA County Public Works Headquarters	12th	Center	0	0699-1	03240053.001	No
		Basement	Center	0	0699-10	03240035.004	No
804	Whittier Lutheran Towers	Roof	Center	0	1071	03232301.003	No
		Basement	Center	0	1069	03232300.004	No
1103	Great Western Savings	Roof	W. core	351	0293-6	03252057.004	No
		Basement	W. core	351	0144	03252021.003	No
1225	San Francisco VA Hospital	7th	Center	5	0767	03261835.002	No
		Basement	Center	5	0604	03261749.001	No
1226	Livermore VA Hospital	7th	Center	305	0854	03251831.002	No
		Basement	Center	305	0602	03251740.001	No
1239	Transamerica Pyramid						Yes
1662	Pacific Park Plaza	30th	Cent. core	350	2141-1	03252335.006	Yes
		Ground	Cent. core	350	0615-6	03252241.005	Yes
5106	Long Beach VA Hospital						Yes
5229	Loma Linda VA Hospital	Roof	Center	0	0230-4	03221849.001 03221953.002	No
		Ground	Center	0	0230-1	03221851.001	No
		Basement	Center	0	none	03221940.002	No
5239	Imperial Norwalk Centre	Roof	Center	0	0128-5	03232051.002	No
		Basement	Center	0	0127-7	03232046.003	No
5245	San Bernardino County Services Building	Roof	North side	0	1578-8	03222146.003	No
			South side	0	1578-9	03222220.004	No
		Basement	South side	0	1462	03222130.001	No
5281	Brinderson Towers #2	Roof	S. corner	330	1034-2	03231804.001	Yes
			Center	330	none	03231841.002	No
		Basement		330		03231813.001	Yes
5407	Millikan Library	Roof	West end	0	0133-16	03241844.001	Yes
		Basement	West end	0	0134-4	03241854.001	Yes

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Earthquake strong-motion data

Recorded strong-motion data available at the time of publication are listed by building in Table 3. Data currently being processed, which will be available soon, are listed in Table 4. Depending on the age and source of the data, processing procedures vary somewhat, and are noted in table footnotes. Magnitudes are moment magnitude unless otherwise noted and were obtained from the Southern California Earthquake Data Center (SCEDC) or the Northern California Earthquake Data Center (NCEDC). Most data recorded prior to the late 1990s were recorded on analog instruments and subsequently digitized. Comments regarding digitizing (such as the existence of stalls in some original analog recordings) are located in the data file headers for each event. Digital data are available from the USGS National Strong Motion Program (NSMP) website (http://nsmp.wr.usgs.gov).

Table 3. Strong-motion data available for study buildings

Station No	Station Name	City	Event Date	Event Name	Lat. (deg)	Long. (deg)	M	Dist. (km)	Peak Base A (g)	Peak Roof A (g)
482	LA County Public Works HQ	Alhambra	09-Feb-71	San Fernando**	34.40	-118.41	6.6	42	0.12	0.18
			21-Feb-73	Point Mugu	34.065	-119.035	5.9	82	0.02	0.02
			01-Oct-87	Whittier Narrows	34.06	-118.08	6.1	7	0.29	0.27
			04-Oct-87	Whittier Narrows Aftershock	34.07	-118.10	5.3*	5	0.14	0.18
			11-Feb-88	Whittier Narrows Aftershock	34.08	-118.05	5.0*	10	0.04	0.03
			28-Feb-90	Upland	34.14	-117.70	5.2	42	0.02	0.03
			28-Jun-91	Sierra Madre	34.26	-118.00	5.8	24	0.13	0.15
			28-Jun-92	Landers	34.20	-116.44	7.3	158	0.03	0.12
			28-Jun-92	Big Bear	34.20	-116.83	6.5	123	0.02	0.06
			17-Jan-94	Northridge	34.21	-118.54	6.7	38	0.16	0.14
			20-Mar-94	Northridge Aftershock	34.23	-118.47	5.2*	34	0.03	0.02
			16-Oct-99	Hector Mine	34.59	-116.27	7.1	182	0.04	0.10
			09-Sep-01	West Hollywood	34.075	-118.379	4.2*	21	0.02	0.008
			28-Oct-01	Compton	33.922	-118.270	4.0*	20	0.008	0.003
			22-Feb-03	Big Bear City	34.310	-116.848	5.2*	122	0.004	0.006
			22-Dec-03	San Simeon	35.71	-121.10	6.5	324	0.004	0.03
804	7215 Bright Avenue	Whittier	01-Oct-87	Whittier Narrows**	34.06	-118.08	6.1	10	0.62	0.53
			17-Jan-94	Northridge	34.21	-118.54	6.7	53	0.153	0.241
1103	Fmr. Great Western Savings	Berkeley	18-Oct-89	Loma Prieta	37.04	-121.88	6.9	99	0.117	0.233
1225	VA Hospital	San Francisco	18-Oct-89	Loma Prieta	37.04	-121.88	6.9	100	0.225	0.341
1226	VA Hospital	Livermore	18-Oct-89	Loma Prieta	37.04	-121.88	6.9	67	0.057	0.148
1239	Transamerica Pyramid	San Francisco	18-Oct-89	Loma Prieta	37.04	-121.88	6.9	97	0.123	0.312
1662	Pacific Park Plaza	Emeryville	18-Oct-89	Loma Prieta	37.04	-121.88	6.9	97	0.232	0.49
			02-Feb-03	Dublin	34.740	-121.937	3.6*	34	0.005	0.008
5106	VA Hospital	Long Beach	17-Jan-94	Northridge	34.21	-118.54	6.7	62	0.06	0.209
5229	VA Hospital	Loma Linda	17-Jan-94	Northridge	34.21	-118.54	6.7	120	0.061	0.165

Station No	Station Name	City	Event Date	Event Name	Lat. (deg)	Long. (deg)	M	Dist. (km)	Peak Base A (g)	Peak Roof A (g)
5239	12440 Imperial Hwy	Norwalk	17-Jan-94	Northridge	34.21	-118.54	6.7	55	0.061	0.148
5245	County Services Building	San Bernardino	28-Jun-92	Landers	34.20	-116.44	7.3	79	0.09	0.36
			17-Jan-94	Northridge	34.21	-118.54	6.7	116	0.045	0.243
5281	Brinderson Towers #2	Irvine	17-Jan-94	Northridge	34.21	-118.54	6.7	88	0.063	0.188
5407	Millikan Library	Pasadena	12-Sep-70	Lytle Creek**	34.27	-117.54	5.2*	56	0.019	0.055
			09-Feb-71	San Fernando**	34.40	-118.41	6.6	39	0.20	0.35
			03-Sep-02	Yorba Linda	33.917	-117.776	4.8*	40	0.006	0.009
			22-Feb-03	Big Bear City	34.310	-116.848	5.2*	119	n/a	0.008
			22-Dec-03	San Simeon	35.71	-121.10	6.5	323	0.002	0.008

* Local magnitude – all other values moment magnitude
** Processed with Caltech "Blue book" procedures (Hudson et al. 1971). Standard USGS procedures (Stephens and Boore 2004) used otherwise.

Table 4. Data currently being processed

Station No	Station Name	City	Event Date	Event Name	Lat. (deg)	Long. (deg)	M	Dist. (km)
5106	VA Hospital	Long Beach	01-Oct-87	Whittier Narrows	34.06	-118.08	5.9	32
			04-Oct-87	Whittier Narrows Aftershock	34.07	-118.10	5.3*	33
5229	VA Hospital	Loma Linda	28-Jun-92	Landers	34.20	-116.44	7.3	76
			28-Jun-92	Big Bear	34.20	-116.83	6.5	42
5239	12440 Imperial Hwy	Norwalk	01-Oct-87	Whittier Narrows	34.06	-118.08	6.1	16
5281	Brinderson Towers #2	Irvine	28-Jun-92	Landers	34.20	-116.44	7.3	144
			28-Jun-92	Big Bear	34.20	-116.83	6.5	113

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