Progress Report: EHP Geodetic Monitoring Operations

The BARD Continuous GPS Network:
Monitoring Earthquake Hazards in Northern California and the San Francisco Bay Area

Reporting Period:	01 March 2018 – 28 February 2019
Cooperative Agreement Number:	*G15AC00081*
C.A. Start Date & End Date:	*Mar 1 2015 – Feb 29 2020*
Geodetic Monitoring Project Name:	*The BARD Continuous GPS Network: Monitoring Earthquake Hazards in Northern California and the San Francisco Bay Area*
Principal Investigator:	*Richard M. Allen*
Co-Principal Investigator:	*Noel M. Bartlow*
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Email Address:	
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Geodetic Project Website:	*http://seismo.berkeley.edu/bard*

Spending and Drawdown status for 3/2018-2/2019

We expect to expend all the current budget year funds by the end of the project period (Project Year 4). A drawdown report is shown as Table 1. It was prepared in mid-January and reflects information from that date, which is the most current information available.

Major Objective & Activities for this Reporting Period:

In the San Francisco Bay Area, about 7 million people live in a geologically complex, tectonically active region that has experienced a number of historic, damaging earthquakes, including the 1868 Hayward, the 1906 San Francisco, and 1989 Loma Prieta earthquakes and most recently, the 2014 South Napa event. In the 19th century alone, 16 earthquakes with M>6 shook the region. Geologic, seismologic, and geodetic evidence suggest that the predominantly strike-slip deformation of the northwest-trending San Andreas fault (SAF) system is an expression of the most active part of the boundary between the Pacific and North American plates. Geodetic measurements, which are particularly useful for detecting deformation and strain on deep structures throughout the seismic cycle, show that Bay Area deformation is both spatially complex and varies with time. Such measurements can now be made continuously in quasi-real time using data from Global Navigation System Satellites (GNSS) receivers. Currently, GNSS satellites are part of the US Global Positioning System (GPS), as well as the European Galileo satellites and other systems in use by countries such as Russia and China. In the past, data have only been available from GPS satellites. Combining measurements from multiple GNSS satellite constellations improves position uncertainties and biases, but requires upgrading GPS receivers to GNSS receivers capable of using multiple satellite constellations. The BARD network has begun the process of upgrading our receivers to newer GNSS models which use both the GPS and Galileo satellite constellations. In 2018, we installed 4 GNSS capable Septentrio receivers at existing BARD sites. Initial upgrades demonstrate observed improvements in various noise measures, with upgrades continuing through 2019 with the end goal of upgrading all BARD sites. Further details are given below.

Invoice/Account Receivable Fund Summary

for Fund 81977

UCB Contact:
Glenda Smith
glenda_smith@berkeley.edu

Award: G15AC00081 Award Start: 3/1/2015 Budget Amount: $ 514,542.00
PI: Richard Allen End: 2/28/2020 Sponsor Name: USDI Geological Survey

Seq Nbr	Item	Orig Item Amt	Accounting Date	As Of Date	Unit	Customer ID	Status	Terms	Due	Days Late	Currency
1	GM00025114	3,871.28	5/4/2015	5/4/2015	GM100	4190	Closed	N30	6/3/2015	-27	USD
2	GM00027431	3,546.37	5/21/2015	5/21/2015	GM100	4190	Closed	N30	6/20/2015	-23	USD
3	GM00027717	6,973.99	6/8/2015	6/8/2015	GM100	4190	Closed	N30	7/8/2015	-28	USD
4	GM00030782	3,793.89	7/14/2015	7/14/2015	GM100	4190	Closed	N30	8/13/2015	-28	USD
5	GM00034278	5,182.69	8/25/2015	8/25/2015	GM100	4190	Closed	N30	9/24/2015	-28	USD
6	GM00035538	3,705.58	9/21/2015	9/21/2015	GM100	4190	Closed	N30	10/21/2015	-29	USD
7	GM00037594	3,053.60	10/12/2015	10/12/2015	GM100	4190	Closed	N30	11/11/2015	-27	USD
8	GM00040190	1,677.78	10/23/2015	10/23/2015	GM100	4190	Closed	N30	11/22/2015	-26	USD
9	GM00041826	3,281.45	11/16/2015	11/16/2015	GM100	4190	Closed	N30	12/16/2015	-27	USD
10	GM00042829	3,519.59	12/8/2015	12/8/2015	GM100	4190	Closed	N30	1/7/2016	-28	USD
11	GM00044264	523.96	12/21/2015	12/21/2015	GM100	4190	Closed	N30	1/20/2016	-28	USD
12	GM00046052	22,699.32	1/27/2016	1/27/2016	GM100	4190	Closed	N30	2/26/2016	-24	USD
13	GM00048383	18,684.82	2/25/2016	2/25/2016	GM100	4190	Closed	N30	3/26/2016	-29	USD
14	GM00050122	14,597.23	3/8/2016	3/8/2016	GM100	4190	Closed	N30	4/7/2016	-24	USD
15	GM00058331	3,761.08	6/7/2016	6/7/2016	GM100	4190	Closed	N30	7/7/2016	-27	USD
16	GM00058691	20,749.76	6/14/2016	6/14/2016	GM100	4190	Closed	N30	7/14/2016	-28	USD
17	GM00061784	7,373.68	7/8/2016	7/8/2016	GM100	4190	Closed	N30	8/7/2016	-25	USD
18	GM00062672	306.61	7/18/2016	7/18/2016	GM100	4190	Closed	N30	8/17/2016	-27	USD
19	GM00066702	8,773.65	8/16/2016	8/16/2016	GM100	4190	Closed	N30	9/15/2016	-27	USD
20	GM00068094	103.49	8/25/2016	8/25/2016	GM100	4190	Closed	N30	9/24/2016	-23	USD
21	GM00068912	6,188.64	9/6/2016	9/6/2016	GM100	4190	Closed	N30	10/6/2016	-24	USD
22	GM00069443	2,414.10	9/13/2016	9/13/2016	GM100	4190	Closed	N30	10/13/2016	-28	USD
23	GM00071861	9,093.43	10/10/2016	10/10/2016	GM100	4190	Closed	N30	11/9/2016	-27	USD
24	GM00074272	9,373.31	11/2/2016	11/2/2016	GM100	4190	Closed	N30	12/2/2016	-25	USD
25	GM00075050	112	11/16/2016	11/16/2016	GM100	4190	Closed	N30	12/16/2016	-28	USD
26	GM00077464	7,750.98	12/7/2016	12/7/2016	GM100	4190	Closed	N30	1/6/2017	-25	USD
27	GM00081265	7,714.73	1/24/2017	1/24/2017	GM100	4190	Closed	N30	2/23/2017	-27	USD
28	GM00082136	4,979.01	2/8/2017	2/8/2017	GM100	4190	Closed	N30	3/10/2017	-25	USD
29	GM00084347	143	2/22/2017	2/22/2017	GM100	4190	Closed	N30	3/24/2017	-28	USD
30	GM00084911	4,159.79	3/7/2017	3/7/2017	GM100	4190	Closed	N30	4/6/2017	-27	USD
31	GM00087317	6,499.06	3/23/2017	3/23/2017	GM100	4190	Closed	N30	4/22/2017	-25	USD
32	GM00088652	4,259.93	4/11/2017	4/11/2017	GM100	4190	Closed	N30	5/11/2017	-24	USD
33	GM00090538	1,201.44	4/24/2017	4/24/2017	GM100	4190	Closed	N30	5/24/2017	-28	USD
34	GM00091679	5,159.97	5/8/2017	5/8/2017	GM100	4190	Closed	N30	6/7/2017	-27	USD
35	GM00094555	9,393.86	6/5/2017	6/5/2017	GM100	4190	Closed	N30	7/5/2017	-28	USD
36	GM00098977	12,859.25	7/5/2017	7/5/2017	GM100	4190	Closed	N30	8/4/2017	-25	USD
37	GM00101973	5,225.70	8/7/2017	8/7/2017	GM100	4190	Closed	N30	9/6/2017	-28	USD
38	GM00104287	112	8/24/2017	8/24/2017	GM100	4190	Closed	N30	9/23/2017	-26	USD
39	GM00105938	7,114.12	9/6/2017	9/6/2017	GM100	4190	Closed	N30	10/6/2017	-28	USD
40	GM00108368	112	9/20/2017	9/20/2017	GM100	4190	Closed	N30	10/20/2017	-28	USD
41	GM00110754	12,188.06	10/16/2017	10/16/2017	GM100	4190	Closed	N30	11/15/2017	-27	USD
42	GM00112121	1,907.80	10/25/2017	10/25/2017	GM100	4190	Closed	N30	11/24/2017	-28	USD
43	GM00115666	5,281.52	11/27/2017	11/27/2017	GM100	4190	Closed	N30	12/27/2017	-28	USD
44	GM00117215	11,119.23	12/19/2017	12/19/2017	GM100	4190	Closed	N30	1/18/2018	-28	USD
45	GM00119420	5,155.83	1/16/2018	1/16/2018	GM100	4190	Closed	N30	2/15/2018	-28	USD
46	GM00121298	3,199.39	1/25/2018	1/25/2018	GM100	4190	Closed	N30	2/24/2018	-26	USD
47	GM00123094	5,162.03	2/7/2018	2/7/2018	GM100	4190	Closed	N30	3/9/2018	-25	USD
48	GM00124494	4,358.54	2/20/2018	2/20/2018	GM100	4190	Closed	N30	3/22/2018	-27	USD
49	GM00125352	7,540.13	3/6/2018	3/6/2018	GM100	4190	Closed	N30	4/5/2018	-28	USD
50	GM00126575	112	3/13/2018	3/13/2018	GM100	4190	Closed	N30	4/12/2018	-24	USD
51	GM00128026	193.59	3/21/2018	3/21/2018	GM100	4190	Closed	N30	4/20/2018	-24	USD
52	GM00133587	11,427.40	5/10/2018	5/10/2018	GM100	4190	Closed	N30	6/9/2018	-25	USD
53	GM00134774	116.13	5/25/2018	5/25/2018	GM100	4190	Closed	N30	6/24/2018	-25	USD
54	GM00136999	5,189.81	6/11/2018	6/11/2018	GM100	4190	Closed	N30	7/11/2018	-28	USD
55	GM00138273	5,190.59	6/26/2018	6/26/2018	GM100	4190	Closed	N30	7/26/2018	-28	USD
56	GM00138895	2,555.16	7/5/2018	7/5/2018	GM100	4190	Closed	N30	8/4/2018	-26	USD
57	GM00142853	17,625.93	8/8/2018	8/8/2018	GM100	4190	Closed	N30	9/7/2018	-25	USD
58	GM00146222	8,280.63	9/10/2018	9/10/2018	GM100	4190	Closed	N30	10/10/2018	-28	USD
59	GM00147950	156.19	9/18/2018	9/18/2018	GM100	4190	Closed	N30	10/18/2018	-28	USD
60	GM00149883	9,579.80	10/10/2018	10/10/2018	GM100	4190	Closed	N30	11/9/2018	-28	USD
61	GM00152991	2,509.66	10/30/2018	10/30/2018	GM100	4190	Closed	N30	11/29/2018	-28	USD
62	GM00154164	6,274.15	11/13/2018	11/13/2018	GM100	4190	Closed	N30	12/13/2018	-28	USD
63	GM00157952	11,075.29	12/12/2018	12/12/2018	GM100	4190	Closed	N30	1/11/2019	-28	USD

Closed and paid invoices 1/11/2019

AWARDED AMOUNT		$407,519.00
AMOUNT BILLED		$376,245.00
AMOUNT INVOICED		$376,245.00
EXPENDITURES THROUGH 01/11/2019		$385,269.97
	Enc.&Pre-Enc.	$1,076.60
		$386,346.57

Table 1: BARD drawdown report. Expenditures for this reporting period are those occurring on or after 3/01/2018.

Understanding how the spatio-temporal variability of plate movement in northern California affects strain accumulation on Bay Area and other faults is critical for assessing the timing and hazards posed by future earthquakes, which is one of the goals of the National Earthquake Hazards Reduction Program (NEHRP). Increasingly, GNSS data can also be used in real time to complement seismic data in providing robust real-time earthquake information particularly for large earthquakes, and, potentially, early warning.

The Bay Area Regional Deformation (BARD) network of permanent, continuously operating GPS receivers has been monitoring crustal deformation in the Bay Area and northern California since 1992. It began as a cooperative effort of the Berkeley Seismological Laboratory at UC Berkeley (BSL), the US Geological Survey (USGS), and several other academic, commercial, and governmental institutions, with the following goals: 1) to determine the distribution of deformation in northern California across the wide Pacific-North America plate boundary from the Sierras to the Farallon Islands; 2) to estimate three-dimensional interseismic strain accumulation along the SAF system in the Bay Area to assess seismic hazards; 3) to monitor hazardous faults and volcanoes for emergency response management; and 4) to provide geodetic infrastructure in northern California in support of related efforts within the surveying and other interested communities. Many of the BSL stations are collocated with broadband seismic stations of the Berkeley Digital Seismic Network (BDSN), allowing the acquisition of GPS data in real time through shared telemetry. The data are archived at the Northern California Earthquake Data Center (NCEDC), where they are available to the public over the internet and in real-time over an Ntrip-caster (http://seismo.berkeley.edu/bard/realtime). BARD also makes its data available to the community through the GPS Seamless Archive Center (GSAC). In the past year, we have begun the transition from GPS to GNSS receivers, as will be described below.

Positions and Time Series

The Berkeley Sesimo Lab is no longer funded to go in-house processing of daily position timeseries. However, daily position time series for BARD stations are processed and made available by the USGS (https://earthquake.usgs.gov/monitoring/gps) and the University of Nevada – Reno geodetic laboratory (http://geodesy.unr.edu/PlugNPlayPortal.php). BSL continues to provide "real-time" 1 Hz baseline timeseries using TrackRT for the BARD network; solutions are available via NTRIP Caster and RabbitMQ broker (https://igs.bkg.bund.de/ntrip/caster). The real-time positions are used by external researchers for a variety of applications and for geodetic earthquake early warning. An example is Berkeley's own G-larmS project. The new Septentrio receivers have onboard Precise Point Positioning (PPP) capabilities, allowing our real-time stream to soon include positions in addition to baselines.

Changes to stated goals and activities:

There were no major changes to the project goals. A new goal of deploying a site or sites to specific targeted locations using existing equipment has been added.

Accomplishments & Changes Implemented in this Reporting Period:

Field Installations and Testing of Septentrio PolaRx5 Receivers: Building off of the rooftop testing reported last year, this year we installed four Septentrio PolaRx5 Receivers. Site SRB1 was upgraded first from a GPS only Topcon Net-G3A on July 20, 2018. Other than the receiver, nothing else was changed at the site. After the upgrade, we observed a decrease in cycle slips per observation, decreased

RMS of MP1 (measure of multipath), and increased SR1 (measure of signal-to-noise). No detectable offset was introduced at the time of receiver change. More recently, sites BRIB, HELB, and MHDL were also upgraded with Septentrio PolaRx5 receivers. Site BRIB has shown the most improvement in both the quality control data and the scatter in daily position timeseries so far (Figures 1 and 2). MHDL and HELB underwent receiver upgrades very recently (within the last 90 days) and have not yet generated enough data for a complete analysis. However, enough data exists to show that no significant visible offset associated with the receiver upgrade has been seen at any of the 4 stations. All four sites have improved noise characteristics with visibly decreased error bars on processed position time series. Example plots for station BRIB are shown below. We have 8 additional Septentrio PolaRx5 receivers at Berkeley which we plan to install at additional existing BARD sites within the next year. We will be proposing to purchase another 21 within the next year as part of the Earthquake Early Warning budget which, if approved, will allow us to complete receiver upgrades on all BARD sites. We expect to complete receiver upgrades at all sites by August 2020.

- *Septentrio set-up:* Mario Aranha spent significant time and effort in this reporting period learning how to properly set-up the Septentrio PolaRx5 receivers for field deployment. This involves direct coordination with Septentrio for each receiver deployment in order to properly configure the onboard PPP service. Mario's experience may be useful to the USGS or other organizations deploying these receivers.

Figure 1: Quality Control measurements for BRIB before and after the receiver change. MP1 and MP2 are measures of the RMS of the multipath part of the pseudorange. Completeness improved, multipath noise decreased, and signal-to-noise increased after the receiver upgrade on 09/01/2018 (vertical red line).

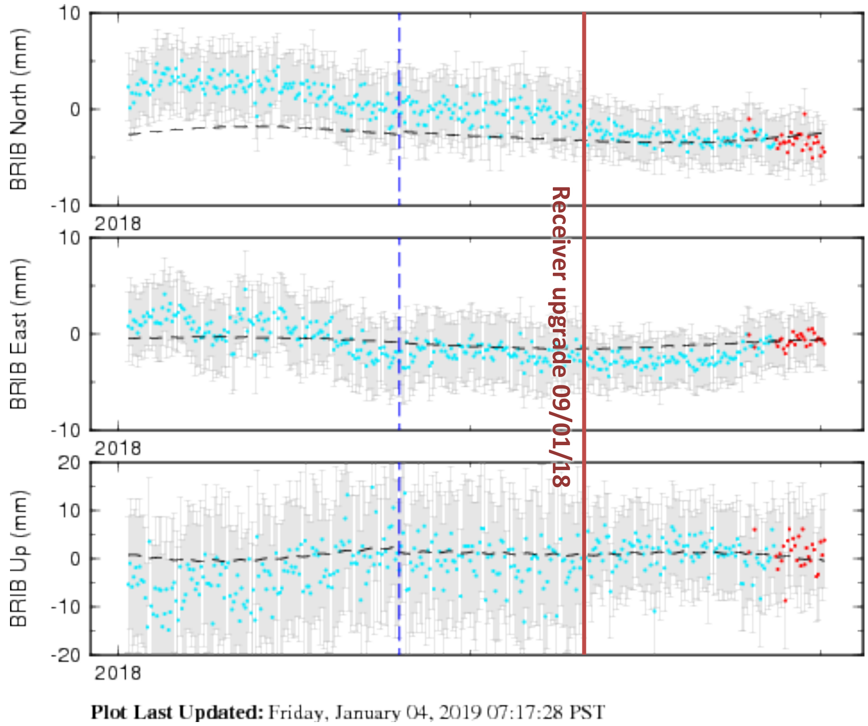

Figure 2: Daily position timeseries for BRIB provided by USGS for the past year. Note that at the time of the receiver upgrade the scatter and the estimated uncertainties decrease in all 3 components. No offset is observed at the time of the receiver upgrade.

Major Goal(s) & Activities for the next Reporting Period

- *Installing more PolaRx5 receivers*: Installation of the Septentrio PolaRx5 receivers has begun as described above. 8 more receivers have already been obtained and remain to be deployed. Initial deployment sites were selected for ease of access in case troubleshooting was required. The BSL field team's current top priority is expanding the seismic network used for Earthquake Early Warning. Therefore, further deployments will be done opportunistically when our field teams when they are near a BARD site. Once EEW seismic deployments are complete, we expect field team resources to be available for receiver upgrades at any remaining sites.
- *Deployment of new stations using existing equipment:* In the past few months Dr. Noel Bartlow, working with graduate student Kathryn Materna, discovered that an area near Cape Mendocino appears to experience changes in coupling on the Cascadia plate interface between the subducting Juan de Fuca plate and the overriding North America plate. While outside of the Bay Area, the Cape Mendocino region is within northern California and it is tectonically complex, with many shallow crustal faults as well the Cascadia subduction plate interface extending to the north. This region is not densely populated; however the probability of large, damaging earthquakes is high. Additionally, there is a possibility that earthquakes in this region can generate large tsunamis affecting coastal regions throughout northern California, including the Bay Area. Coupling on the southern Cascadia plate interface appears to change in a specific location suddenly and permanently following the passage of low-frequency seismic waves from large (M 6.5+) regional earthquakes. This discovery was made using daily position timeseries from stations within Plate Boundary Observatory network, because no BARD stations exist within close enough proximity to the coupling change feature, although the region is within the coverage area of the BARD network. PBO Station coverage in this area, which also

includes the complex Mendocino triple junction, is adequate for many applications but a few additional, well placed stations could greatly improve our scientific understanding of this newly observed coupling change phenomenon. For this reason, the BARD network plans to deploy an additional station or stations in this region using existing equipment. Detecting and understanding time-dependent changes in coupling is critical to assessing large earthquake hazards, especially in subduction zone environments. Additionally, sites may be deployed using existing equipment to other areas of tectonic interest in northern California in collaboration with UC Berkeley Seismological Laboratory faculty and researchers.

Problems encountered and/or Concerns

Following the departure of Dr. Diego Melgar for the university of Oregon in fall 2017, a new geodetic researcher, Dr. Noel Bartlow, joined the UC Berkeley Seismological Laboratory in June 2018. A request will be filed to add Dr. Bartlow as a BARD network co-PI. Dr. Bartlow is new to BARD but brings years of experience conducting and advising research in tectonic geodesy. She is rapidly getting up to speed on the current status of the BARD network and upgrades. Mario Aranha, who has been handling BARD data and processing for several years has stepped up to take over more responsibility in the past year, including setting up and overseeing initial installations of our new Septentrio GNSS recievers. Our operations manager Peggy Hellweg also provides continuity of station and deployment expertise.

Map and List of Geodetic Stations:

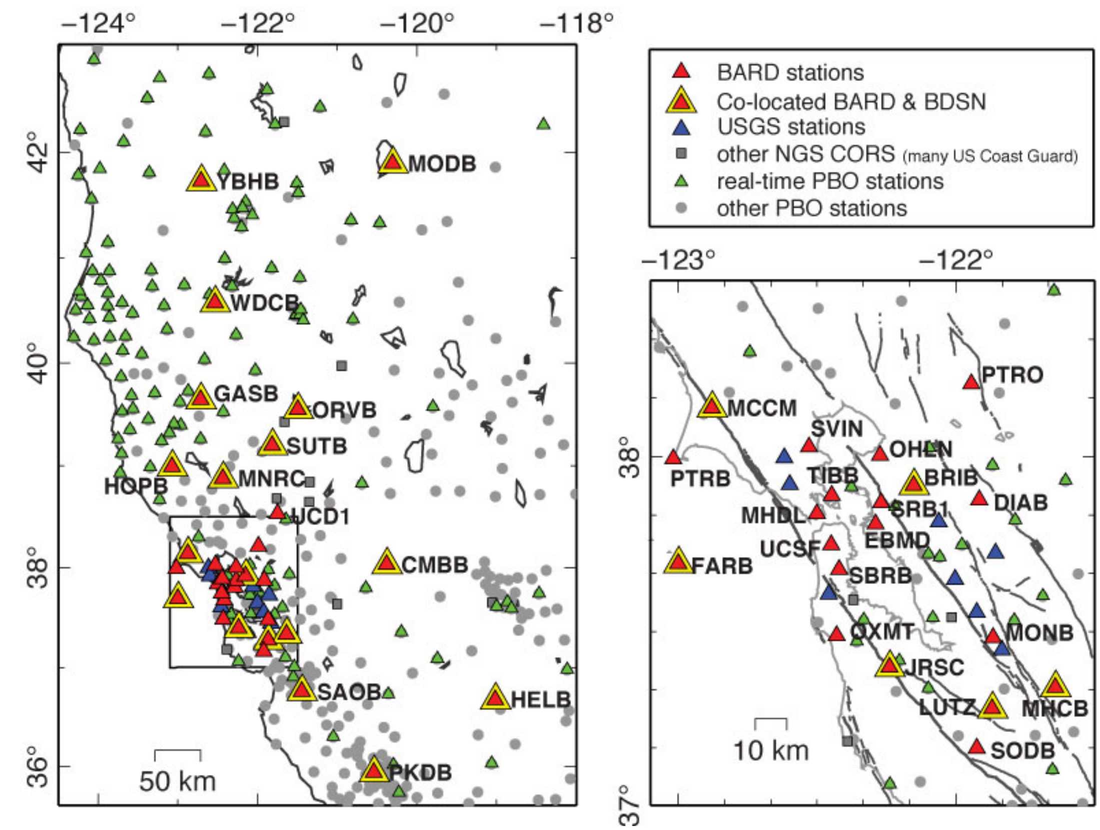

Figure 1: Map of the BARD network and surrounding PBO and USGS sites in northern California. Black rectangle in large scale map on left shows the extent of the small scale figure on the right.

Table 2: *BARD station information summary*

	Site	Receiver	Ant.	Telem.	Samp. Rate	Real-time?	Colloc. Net.	Install Date	Location
1	BRIB	PolaRx5	CR	T1	1Hz	Yes	BDSN	8/6/93	*Russell Reserve*
2	CMBB	NET-G3A[f]	CR	Int	1Hz	Yes	BDSN	12/9/93	*Columbia College*
3	DIAB	NETRS	CR	CM	1Hz	Yes		5/21/98	*Mt. Diablo*
4	EBMD	NET-G3A[f]	CR	Int	1Hz	Yes		8/2/99	*East Bay MUD Headquarters*
5	FARB	NETRS	CR	R-Int	1Hz	Yes	BDSN	1/27/94	*Farallon Islands*
6	GASB	NET-G3A	CR	R-[&]	1Hz	Yes	BDSN	6/17/11	*Alder Springs*
7	HELB	PolaRx5	CR	R-CM	1Hz	Yes	BDSN	12/19/13	*Miramonte*
8	HOPB	NET-G3A[f]	CR	CM	1Hz	Yes	BDSN	8/26/95	*Hopland Field Station*
9	JRSC	NET-G3A[f]	CR	Int	1Hz	Yes	BDSN	11/30/11	*Jasper Ridge Biological Preserve*
10	LUTZ	NET-G3A[f]	CR	Int	1Hz	yes	BDSN	5/18/96	*SCC Communications*
11	MCCM	NET-G3A[f]	CR	WISP	1Hz	yes	BDSN	9/28/11	*Marconi Conference Center*
12	MHCB	NETRS	CR	Int	1Hz	yes	BDSN	6/14/96	*Lick Observatory*
13	MHDL	PolaRx5	CR	Int	1Hz	yes	Mini-PBO	9/12/06	*Marin Headlands*
14	MNRC	NET-G3A	CR	VSAT	1Hz	yes	BDSN	7/7/11	*McLaughlin Mine*
15	MODB	NETRS	CR	VSAT	1Hz	yes	BDSN	11/11/99	*Modoc Plateau*
16	MONB	NET-G3A[f]	CR	CM	1Hz	yes		7/31/98	*Monument Peak*
17	OHLN	NET-G3A[f]	CR	CM	1Hz	yes	Mini-PBO	11/21/01	*Ohlone Park*
18	ORVB	NET-G3A[f]	CR	CM	1Hz	yes	BDSN	11/21/96	*Oroville*
19	OXMT	NET-G3A[f]	CR	CM	1Hz	yes	Mini-PBO	2/12/04	*Ox Mountain*
20	PKDB	NETRS	CR	R-T1	1Hz	yes	BDSN	9/20/96	*Bear Valley Ranch*
21	PTRB	NETRS	CR	R-CM	1Hz	yes		8/14/98	*Point Reyes Lighthouse*
22	PTRO	NET-G3A[f]	CR	CM	1Hz	yes	BDSN	12/8/11	*Potrero Hills*
23	SAOB	NETRS	CR	CM	1Hz	yes	BDSN	8/21/97	*San Andreas Observatory*
24	SBRB	NET-G3A[f]	CR	CM	1Hz	yes	Mini-PBO	8/21/08	*San Bruno Replacement*
25	SODB	NETRS	CR	R-CM	1Hz	yes		5/18/96	*Soda Springs*
26	SRB1	PolaRx5	CR	Fiber	1Hz	yes		11/14/06	*Seismic Replacement Building*
27	SUTB	NETRS	CR	R-CM	1Hz	yes	BDSN	3/27/97	*Sutter Buttes*
28	SVIN	NET-G3A[f]	CR	CM	1Hz	yes	Mini-PBO	11/20/03	*St Vincents*
29	TIBB	NET-G3A[f]	CR	R-Int	1Hz	yes		6/16/94	*Tiburon*
30	UCD1	NETRS	CR	Int	1Hz	yes		5/19/96	*UC Davis (operated by UC Davis)*
31	UCSF	NET-G3A[f]	CR	Int	1Hz	yes		12/5/07	*UC San Francisco*
32	WDCB	NET-G3A[f]	CR	CM	1Hz	yes	BDSN	5/6/11	*Whiskeytown Dam*
33	YBHB	NETRS	CR	CM	1Hz	yes	BDSN	10/24/96	*Yreka Blue Horn Mine*

Receivers are: Trimble NETRS, (NETRS) and Topcon Net-G3A (Net-G3A). The telemetry types listed are R = Radio, Int = Internet, VSAT = Satellite, T1 = Shared or private T1 line, CM = Cellular Modem, WISP = Wireless ISP. Telemetry often includes a radio hop from the GPS site to the seismic vault, indicated by an initial R. All are equipped with Ashtech or Topcon choke ring antennas (CR). (*) . Topcon receivers with upgraded firmware are indicated by an [f]. ([&]) There is currently no telemetry from GASB. We hope to have a replacement for Frame Relay soon.

Metadata:

There are no updates since the last reporting period. Metadata and log files are available at http://seismo.berkeley.edu/station_book/bard_station_book.html

Data Management Practices:

Continuous data archival

All data collected from BARD/BSL stations are publicly available at the NCEDC (http://www.ncedc.org, ftp://www.ncedc.org/pub/gps), both as raw data and converted into RINEX format. High-rate (1 Hz) data are additionally downsampled to 15-sec sampling and archived in RINEX format to facilitate low-rate processing. The NCEDC also archives raw and RINEX data from 8 continuous stations operated by the USGS, Menlo Park, on a daily basis, as well as from those that are telemetered directly to the BSL though operated by another agency (UCD1 & EBMD).

Data from five of our sites (HOPB, MHCB, CMBB, OHLN, YBHB) are sent to the National Geodetic Survey (NGS) in the framework of the CORS (Continuously Operating Reference Stations) project (http://www.ngs.noaa.gov/CORS/). The data from these five sites are also distributed to the public through the CORS ftp site.

Campaign data archival

As part of the activities funded by the USGS through the BARD network, the NCEDC is the principal archive of the 7000+ survey-mode occupations collected by the USGS since 1992. The initial dataset archived was the survey-mode GPS data collected by the USGS Menlo Park for northern California and other locations. Significant quality control efforts were implemented by the NCEDC to ensure that the raw data, scanned site log sheets, and RINEX data are archived for each survey. All of the USGS-MP GPS data transferred to the NCEDC (1992-2014) have been archived and are available for distribution through the NCEDC ftp server (http://www.ncedc.org/ncedc/gps.html).

Real-time streaming

Our data dissemination program includes real time streaming from all BARD/BSL sites in both RTCM3.0 and BINEX formats. The BSL is also the public portal for real-time streams from the 8 continuous GPS stations operated by the USGS, Menlo Park. The NTRIP-caster we are using to stream the BARD and USGS data is also being used to relay RT17 (Trimble proprietary format) data from stations in the Parkfield area to UC San Diego. Access to the real-time data streams requires an account, though anyone may request and receive an account. Details are on the streaming webpage (http://seismo.berkeley.edu/bard/realtime).

Real-time position archival

As the Septentrio sites come online we will begin to receive real-time PPP solutions from those sites. They will be treated as 1Hz displacement seismograms and will be archived with the seismic data at the NCEDC and available through web services and other portals for seismic data. The PPP solutions will also be added to the real-time data stream described above.

Time Series and station specific information
BSL station pages are accessible from http://seismo.berkeley.edu/bard/bard_station_book/bard_station_book.html. These pages give information and meta data on each station, including quality control measurements such as multipath noise levels. Time series are no longer processed by BSL, but can be obtained from the USGS or UNR as described earlier in this report.

Continuity of Operations and Response Planning:

Many BARD stations are co-located with BDSN seismometers and take advantage of the shared power and telemetry infrastructure. The BDSN and the Northern California Seismic Network (NCSN, operated by the USGS, Menlo Park) are together responsible for earthquake detection and notification in Northern California and they have been designed accordingly to perform well following an earthquake. Nonetheless, in the event of a telemetry outage, on-site data recording should continue and data will be available for recovery once communication is re-established.

Barring network outages, BARD data and results will quickly be available to the scientific community. All BARD stations have continuous telemetry and coseismic displacements can be determined as soon as sufficient data are available (rule of thumb: ~4 hours for traditional processing of low rate data). Data are streamed in real time in BINEX and RTCM formats and raw and RINEX data files from all stations are regularly made available to the general public within one hour of the change in UTC day. These data could be made available more quickly by special request.

We continue to develop means of incorporating data from BARD stations more intimately into existing seismic earthquake response systems. Establishing real time streaming and processing of our data is just a first step in accomplishing our goal of integrating geodetic data into the Northern California Seismic System (NCSS) in collaboration with the USGS. The ongoing EEW and finite fault determination efforts described above are examples. The goal is outlined in a Memorandum of Understanding (MOU) between the BSL and the USGS. As part of the MOU, the BSL and Menlo Park exchange geodetic data in real time and perform parallel real time processing in support of rapidly producing results and products that are useful to emergency personnel and scientists following an event.