

Westlands Water District Subsidence Benchmark Survey

Prepared for:



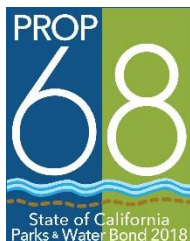
Westlands Water District

Prepared June 2021



Blair,
Church
& Flynn

Blair, Church & Flynn Consulting Engineers
451 Clovis Avenue, Suite 200
Clovis, CA 93612
www.bcf-engr.com



Funding for this project has been provided in full or in part from the Water Quality, Supply, and Infrastructure Improvement Act of 2014 (Proposition 1) and the California Drought, Water, Parks, Climate, Coastal Protection, and Outdoor Access For All Act of 2018 (Proposition 68), and through an agreement with the State Department of Water Resources."

Table of Contents

Overview	2
Purpose.....	2
Methodology.....	2
Benchmark Installation.....	2
GPS Equipment & Procedures	4
Adjustment Results	7
Continuously Operating Reference Stations.....	7
Final Adjustment	8

Figures

Figure 1. Monument set in Meter Base (left) and Monument set in 10" concrete(right)	3
Figure 2. South Benchmark Sites	6
Figure 3. North Benchmark Sites	7

Tables

Table 1. Benchmark Occupation Times	4
---	---

Appendices

Appendix A: Monument Diagrams	
Appendix B: NGS Data Sheets	
Appendix C: GNSS Baseline Processing	
Appendix D: Star*Net Listing	
Appendix E: GNSS Surveying Standards & Specifications, 1.1	

Overview

Purpose

Westlands Water District (District) is the Groundwater Sustainability Agency (GSA) for the Westside Subbasin (DWR's Bulletin 118, 5-22.09). The Westside Subbasin (Subbasin) resides in the greater San Joaquin Valley Groundwater Basin in Fresno and Kings Counties and is 626,000 acres in size. The Department of Water Resources (DWR) identified the Westside Subbasin as a critically over drafted subbasin in January 2016.

The objective of the Subsidence Benchmark Network Project (Project) is to install fifteen (15) benchmark monuments to enhance the Subbasin's understanding of the cause and effect of subsidence in subsidence prone areas along the San Luis Canal as part of the Groundwater Sustainability Plan (GSP) development. The Project will reduce data gaps in the Subbasin, enhance the GSA's ability to monitor and report sustainability indicator objectives, groundwater storage, and subsidence. The vertical data from benchmarks will be used to refine the understanding of spatial occurrence of subsidence and improve the subbasin's hydrogeologic conceptualization. The Project compliments actions proposed in the GSP to reduce data gaps and is a key tool to implement projects and management actions in the Subbasin.

Methodology

Benchmark Installation

Pre-planning informed the selection of benchmark locations in the two regions of concern in the Westside Subbasin. The sites were selected based on the following three criteria: ease of access, location within District Franchise and ability to be occupied by Global Positioning System (GPS). This pre-planning was conducted using satellite imagery through Google Earth. The sites were selected to cover the expansive area impacted by subsidence, within the region delineated by Westlands Water District. We identified locations that were subject to large amounts of groundwater pumping and placed the benchmarks near the sites. This would help determine the ground water is being impacted by the well pumping.

After the site selections were approved by the District, site visits were performed at each of the fifteen (15) proposed benchmark locations. These site visits allowed for confirmation that the areas selected would meet the above three criteria. If any of the sites failed to meet these standards, then the site was adjusted to adhere and given final approval by the District.

Following the site visit, the installation of the benchmarks was performed on December 3rd, 2020. Thirteen (13) of the fifteen (15) benchmarks were set on the concrete meter base of the District's delivery turnouts (Figure 1). The following material was used to set the benchmarks in the concrete structure:

- Epoxy (Devon – 1500 psi)

- Drill with a 1" drill bit for the monument stem



Figure 1. Monument set in Meter Base (left) and Monument set in 10" concrete(right)

The two (2) additional sites (BM#3 & BM#5) required concrete monuments to be established in the dirt of the easement location of the delivery pipes (Figure 1). The monuments were set with the following material:

- 10-inch concrete form tube cut to the depth of 3-feet.
- 80-lb of "High-strength 5,000 plus concrete mix" (Sakrete). This concrete was selected due to its ability to be set in cold weather.
- 50-lb of all purpose gravel. This was used as base and backfill along the perimeter of the form tube.
- 50-lb of multi-purpose sand. The sand was utilized as base and backfill for the perimeter of the form and served as an additive to the concrete.
- #5 rebar. Three equally spaced #5 rebar, 1.5 feet in length, were placed in the concrete, while it was being poured.
- Shovel
- Digging bar
- Tamper
- Trowel

The brass cap benchmarks were provided by the District and stamped with a benchmark number, then set in their final location. The monument diagrams included in this report detail the monument type and location, along with coordinate data.

It should be noted that the benchmark numbers range from one (1) to sixteen (16). Site #6 was originally selected to be part of the master benchmark network; however, this point was later changed to a check point. Site #6 (also callout as CHK 6), is a 3/4" diameter by 2.5 feet long iron pipe, with a red plastic cap labeled "Control" set flush in the ground. The monument is referenced in this report, as the sequencing and naming of the stamped monuments included #6. It must be said that this point was not set at the caliber as the other control points and will be only used if other benchmarks are destroyed in the future.

GPS Equipment & Procedures

Five (5) Leica GS-14 receivers were used for the acquisition of the data for the Benchmark Survey. Each receiver was set to collect the static data with a 15-degree mask and at a 5 second epoch interval utilizing a fixed height 2-meter rod.

All benchmarks were occupied with a minimum of two sessions each with a minimum occupation time of 30 minutes, while 50 percent of the stations were occupied with a third session, all having a minimum two-hour sidereal time displacement. When possible, benchmarks were occupied for 1.5 hours to improve final coordinate spatial accuracy. The field procedures followed were for a survey with anticipated data results having a spatial accuracy classification of "Vertical, 0.5 centimeters to 2.0 centimeters" at the 95 percent confidence interval as outlined in "GNSS Surveying Standards and Specifications, 1.1," a joint publication of the California Land Surveyor's Association (CLSA) & the California Spatial Reference Center (CSRC), dated December 10, 2014 (see Appendix E). Benchmark "CHK 6" was the only point not occupied at this duration, as it was used in the local benchmark network and not directly tied to the CORS. As mentioned above, this control point was only set as a checkpoint. The table below details the session times for the benchmark locations, for more detail on the static network configurations, see Appendix C. The times are dependent on the static baseline length, when calculating the benchmark position.

Table 1. Benchmark Occupation Times

Point Number	Point Description	Session 1 (hours)	Session 2 (hours)	Session 3 (hours)
1	BM#1	1.5	1.5	0.5
2	BM #2	1.5	1.5	0.5
3	BM #3	1.5	1.5	-
4	BM #4	1.5	1.5	0.5
5	BM #5	1.5	0.5	-
6	CHK 6	0.5	0.5	-
7	BM #7	1.5	1.5	0.5
8	BM #8	1.5	0.5	-
9	BM #9	1.5	1.5	.5
10	BM #10	1.5	1.5	.5
11	BM #11	1.5	1.5	.5
12	BM #12	1.5	1.5	-
13	BM #13	1.5	1.5	1.5
14	BM #14	1.5	1.5	-
15	BM #15	1.5	1.5	-
16	BM #16	1.5	1.5	-

During this campaign, the planetary K-index (National Oceanic and Atmospheric Administration) was verified not to exceed 4.¹ This index is referenced when assessing the magnitude of geomagnetic storms. Geomagnetic storms have the potential of modifying the path of radio signals, which in turn creates errors in the position of GPS collected data. In addition to this assessment, the satellite coverage and positioning on the benchmark points was monitored during occupation.

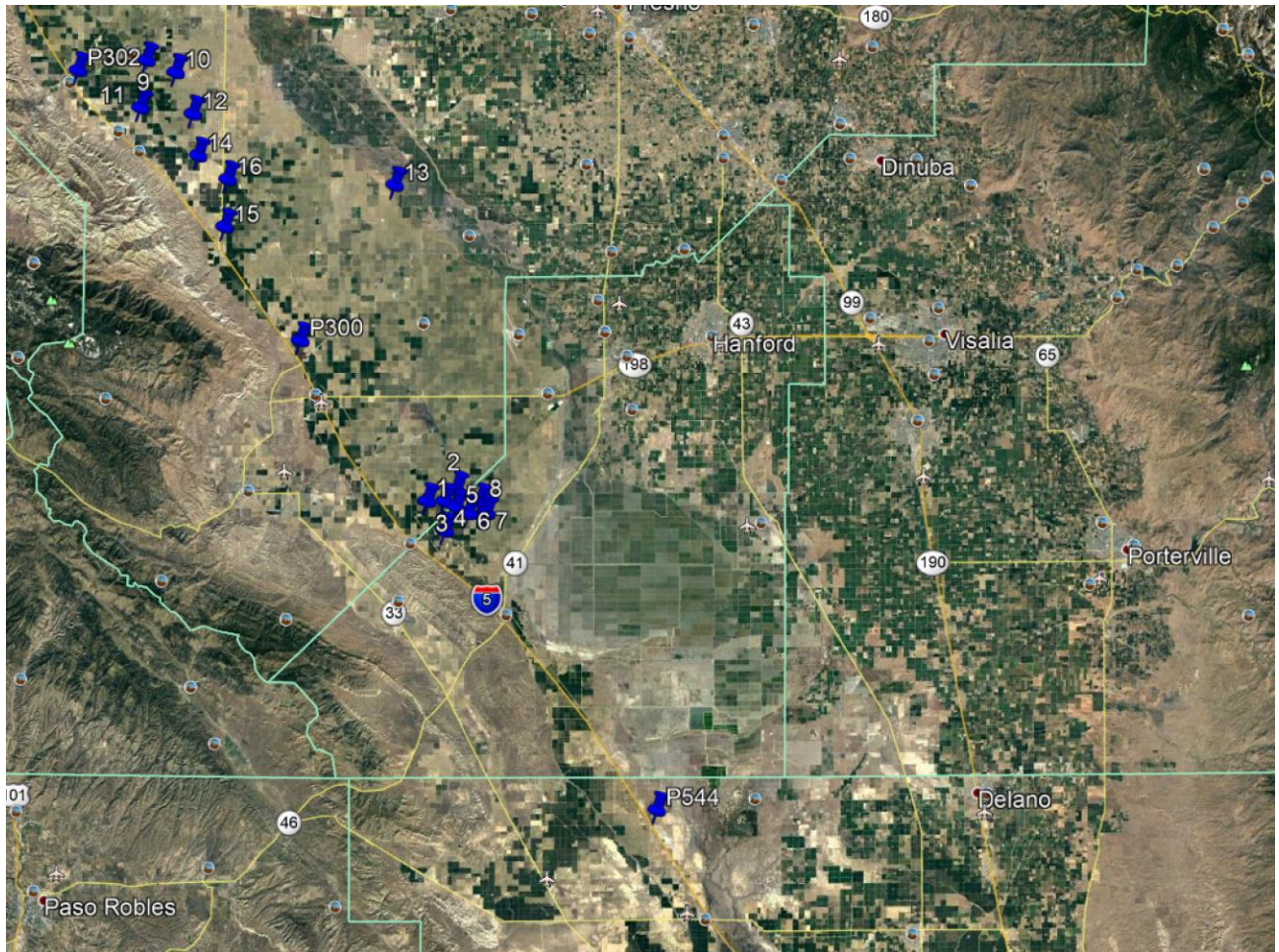


Figure 2. CORS & Benchmark Sites

Figure 2 details the location of the CORS (P544, P302, & P300) and benchmarks (1-5 & 7-16) set. Point number 6 or “CHK 6” is also shown on this diagram.

¹ “Planetary K-Index.” *Planetary K-Index* | NOAA / NWS Space Weather Prediction Center, National Oceanic and Atmospheric Administration, 2021, www.swpc.noaa.gov/products/planetary-k-index.

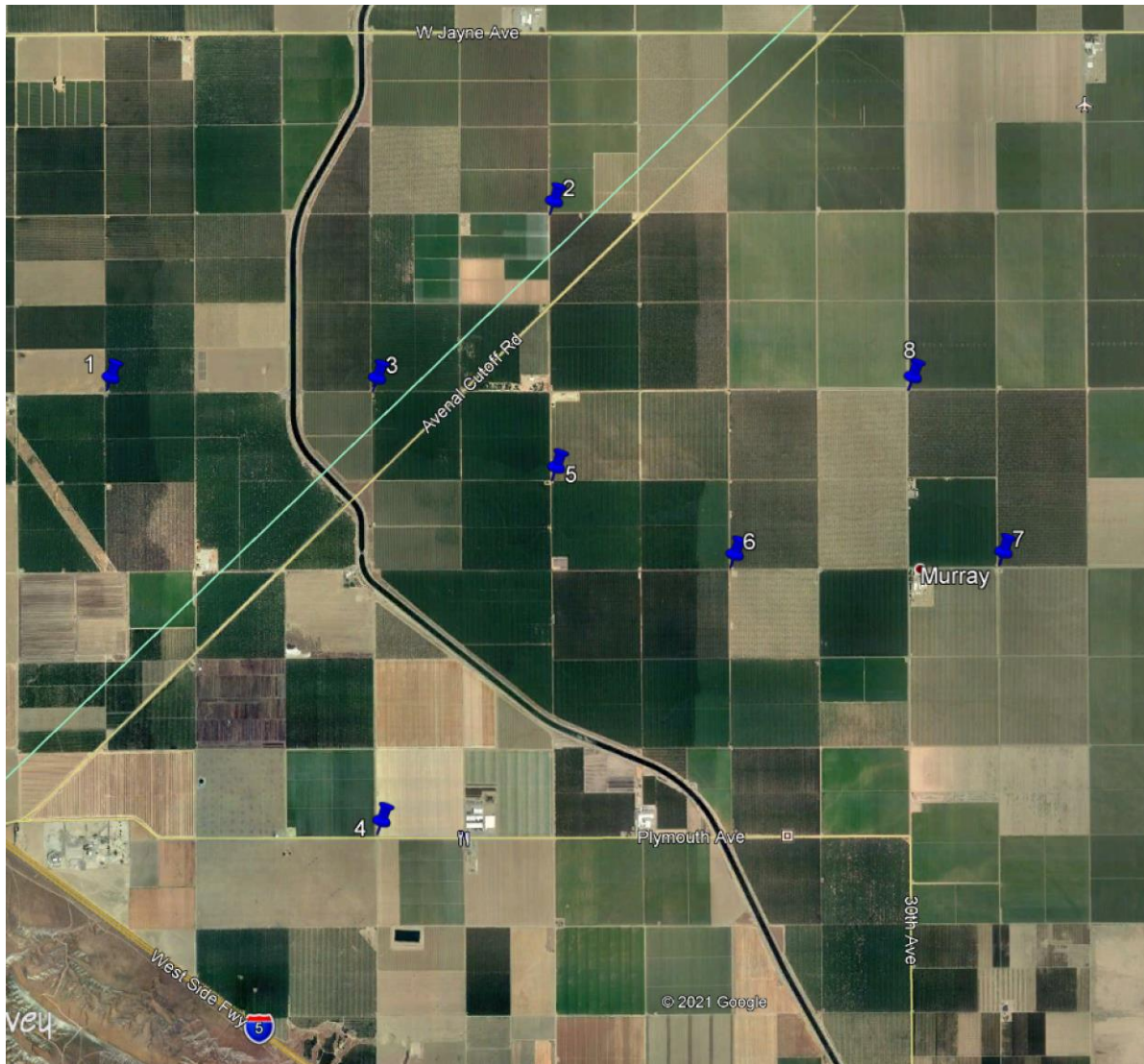


Figure 3. South Benchmark Sites

Figure 3 displays the benchmarks set on the Southern Region of this benchmark survey and their locations.

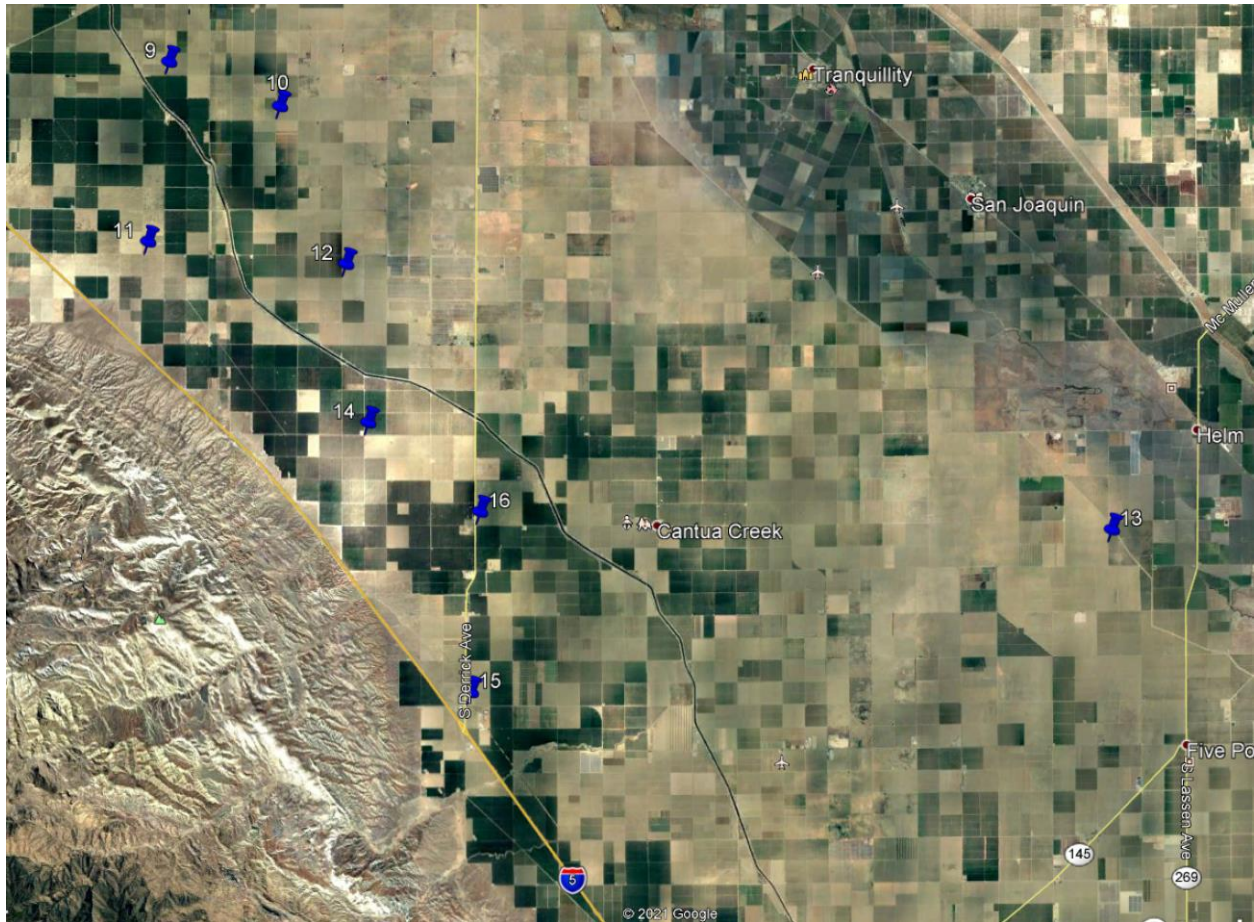


Figure 4. North Benchmark Sites

Figure 4 displays the benchmarks set on the Southern Region of this benchmark survey and their locations.

After the field survey was completed, the post-processing was performed utilizing Leica Infinity (Version 3.4.2). During this process, the precise ephemeris generated by the International GNSS Service (IGS) was referenced. To adjust and analyze vectors, Star*Net (Version 10.0.15.974) was used. The establishment of the coordinates at all stations is described in the adjustment computations.

Adjustment Results

Continuously Operating Reference Stations

This static survey was tied to Continuously Operating Reference Stations (CORS) managed by the National Oceanic and Atmospheric Administration. CORS are reference stations with permanent GNSS receivers, which allowed for the calculation of precise positions for the benchmark locations when it is tied to the CORS network.

The first step to calculate the benchmark positions was processing the data against the published RINEX (Receiver Independent Exchange Format) data for three (3) reference stations: “P302”, “P300” and “P544”

(See Appendix B for additional information). Using this format, the data can be post processed with the static data collected at the benchmark locations. The values for each of the stations were held in the adjustment through Star*Net. “P302” is the only vertical and horizontal constraint for the static network, where “P300” was held for the basis of bearings and “P544” was a check point. The latitude, longitude, and ellipsoidal heights for these three stations are based on the National Geodetic Surveys (NGS) data sheets obtained from the NGS website.² The data was also converted to the California Coordinate System of 1983 (CCS83), NAD83(2011), Zone 4, Epoch 2010, as this is a widely used system in the State of California.

As stated on in the data sheets, all data is based on the North American Vertical Datum 1988. The “Geoid 18” geoid model was applied to the ellipsoidal heights to calculate the orthometric heights for this project. Neither a thorough analysis of the geoid or leveling was performed as part of this survey. For full detail of the vector data and processing refer to Appendix “C”.

Final Adjustment

The final coordinates values for the benchmarks are published below.

Table 2. Benchmark Data -CCS83

Point Number	Northing*	Easting*	Orthometric Height* (NAVD88)	Point Description
1	1924593.278	6241447.261	350.94	BM #1
2	1929590.563	6254678.762	290.78	BM #2
3	1924438.645	6249345.246	303.52	BM #3
4	1911323.849	6249255.155	408.25	BM #4
5	1921709.134	6254607.555	281.28	BM #5
6	1919041.098	6259855.417	263.96	CHK 6
7	1918978.492	6267821.723	245.45	BM #7
8	1924208.121	6265223.373	258.29	BM #8
9	2122313.117	6117471.32	306.23	BM #9
10	2116836.809	6130546.275	257.23	BM #10
11	2101166.777	6114629.946	437.19	BM #11
12	2098123.896	6138086.613	238.72	BM #12
13	2065335.952	6228273.485	194.23	BM #13
14	2079412.177	6140400.366	398.72	BM #14
15	2047467.665	6152016.888	447.36	BM #15
16	2068690.904	6153483.703	410.22	BM #16

***All data is displayed in US Survey Feet**

² “Finding Survey Marks and Datasheets.” *Survey Mark Datasheets*, National Geodetic Survey, 2021, geodesy.noaa.gov/datasheets/.

Table 3. Benchmark Data -WGS84

Station	Latitude	Longitude	Ellipsoidal Height	Point Description
1	36-06-32.301388	-120-05-02.567215	238.86	BM#1
2	36-07-23.163457	-120-02-21.984712	178.71	BM #2
3	36-06-31.643007	-120-03-26.300291	191.39	BM #3
4	36-04-21.947730	-120-03-25.638932	296.07	BM #4
5	36-06-05.220300	-120-02-21.812922	169.11	BM #5
6	36-05-39.394202	-120-01-17.521689	151.75	CHK 6
7	36-05-39.601993	-119-59-40.452669	133.24	BM #7
8	36-06-31.048138	-120-00-12.776681	146.16	BM #8
9	36-38-50.777238	-120-30-51.258137	196.02	BM #9
10	36-37-58.639019	-120-28-09.796804	146.90	BM #10
11	36-35-21.250638	-120-31-22.007810	327.21	BM #11
12	36-34-54.745150	-120-26-33.842845	128.36	BM #12
13	36-29-42.506726	-120-08-03.360656	84.39	BM #13
14	36-31-50.073332	-120-26-02.050998	288.57	BM #14
15	36-26-35.904239	-120-23-34.050101	337.41	BM #15
16	36-30-05.965617	-120-23-19.855344	299.99	BM #16
P300	36-18-15.924880	-120-16-37.079390	452.48	CORS P300
P302	36-38-05.005320	-120-37-06.820640	404.39	CORS P302
P544	35-43-52.551177	-119-44-16.875237	112.24	CORS P544

***All data is displayed in US Survey Feet**

Appendix A: Monument Diagrams

Appendix B: NGS Data Sheets

Appendix C: GNSS Baseline Processing

Appendix D: Star*Net Listings

Appendix E: GNSS Surveying Standards & Specifications, 1.1
