Combined Project Report [DRAFT]
City of Davis & Reclamation District 2068
Deep Aquifer Study Benchmark Projects
July 31, 2004

Background

The purpose of these projects was to install four new benchmarks and establish North American Vertical Datum of 1988 (NAVD88) elevations upon them. Three of the new marks are in Yolo County (RWF1, SUTTER, and W028) and one is in Solano County (RD2068). The projects were combined in order to take advantage of the economies of scale afforded by their proximity and common technical requirements.

Three of the new benchmarks were positioned via Global Positioning System (GPS) observations. This approach was chosen in favor of geodetic leveling because of the comparable accuracy and substantial cost savings the GPS method offers when benchmark spacing exceeds a few kilometers, and because of the redundancy of reference benchmarks inherent in the method. The latter is particularly important when the reference benchmarks may be susceptible to land subsidence.

The fourth station (W028) was **[will be]** connected via differential leveling owing to its proximity to station SUTTER.

The GPS element was observed in accordance with National Geodetic Survey (NGS) height modernization guidelines (NOAA Technical Memorandum NOS NGS-58, Guidelines For Establishing GPS-Derived Ellipsoid Heights) using the 2cm specification, except that session times were extended to 45 minutes and, in some cases, 60 minutes.

Each of the new benchmark stations consists of a 2" aluminum disk grouted into a drill hole in the top of a massive concrete structure. A GPS network diagram (Appendix A) shows the approximate locations of the GPS benchmarks. (Station W028 is not shown.) Complete descriptions of each station are provided in Appendix B.

Technical Overview and Results

Data from three Continuously Operating Reference Stations (CORS) were incorporated into the project. Each is listed below along with its NGS Permanent Identification Number (PID) and approximate location:

```
Station      PID          Location

UCD1         AI4467       UC Davis campus
PLSB         DG5211       Woodland
TMSB         DG4799       West Sacramento
```

The first is owned by the University of California at Davis and managed by the Bay Area Deformation Network, while the latter two are cooperative CORS owned and operated by Haselbach Surveying Instruments.

GPS observations were made at eight ground stations within the vicinity of the two projects. These stations were previously included in NAVD88 height modernization projects. Six of the pre-existing stations were positioned during the 2002 Yolo Subsidence Network campaign (NGS Project No. GPS1790/B), and two of them as part of the 1997 Delta campaign (NGS Project No. GPS1308/B):

```
Station Name           PID          4-Char ID        Project ID

ALHAMBRA               AI5051       ALHA             GPS1790/B
ANDREW                 AE9864       ANDR             GPS1790/B
COY DUMP               AI5059       COY1             GPS1790/B
CALDWELL               AE9863       CALD             GPS1790/B
HPGN D CA 03 DG        AC9223       03DG             GPS1790/B
MILLAR                 AE9861       MILL             GPS1308/B
PLAINFIELD             AI5068       PLAI             GPS1790/B
SURVEYOR               AE9862       SURV             GPS1308/B
```
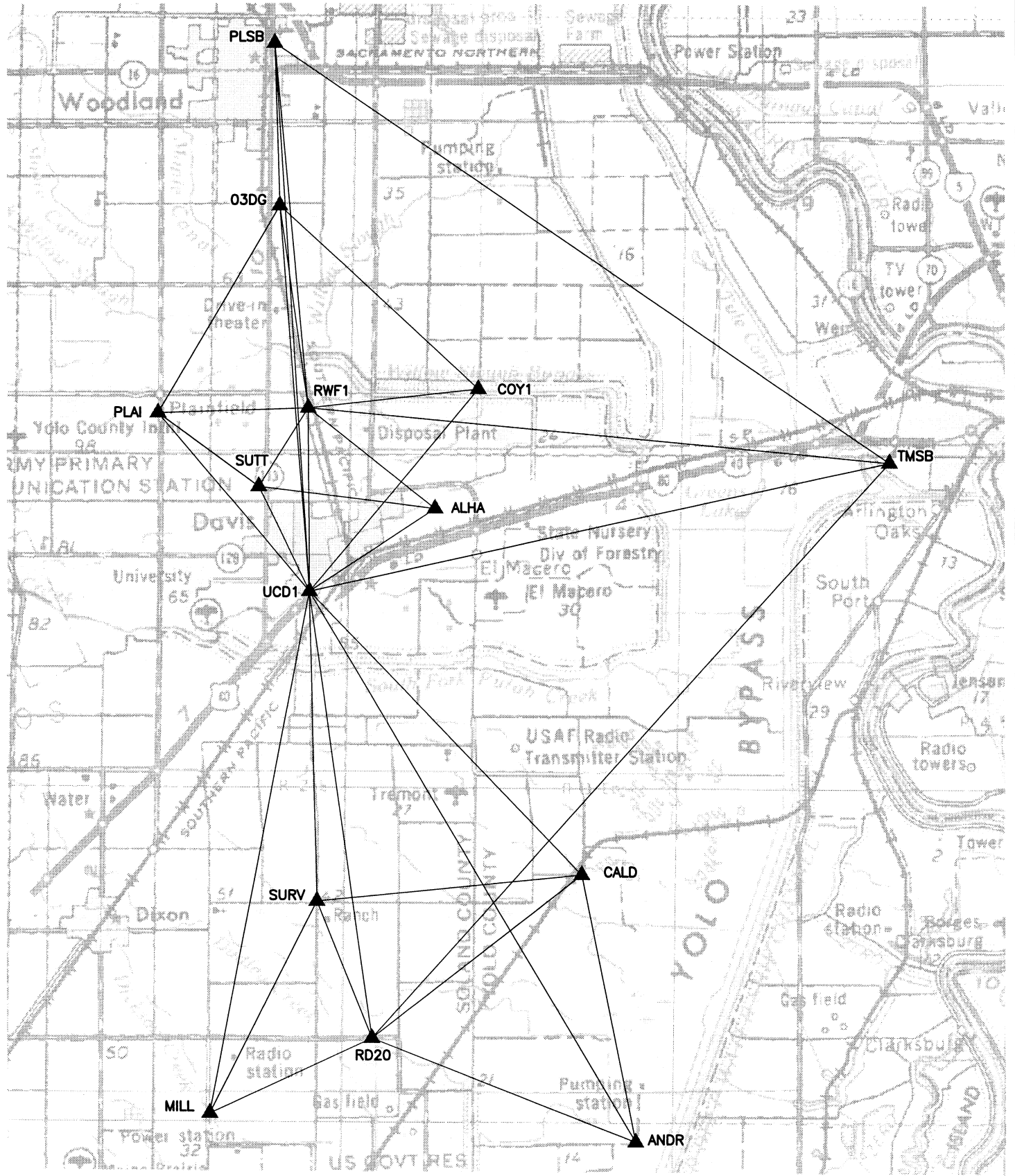
These eight stations, along with the three CORS, were used to constrain the network adjustment. They are generally referenced by their 4-character identifiers throughout the remainder of this report.

The fourth new station, W028, was given an NAVD88 elevation by means of geodetic leveling.

Final adjusted NAVD88 elevations for the new benchmarks, rounded to the nearest 0.01m and 0.05 foot in keeping with the accuracy of the methods employed, are as follows:

```
Station     Elevation     Elevation
            (Meters)      (Feet)

RWF1        14.63         48.00
RD20        12.41         40.70
SUTT        14.87         48.80
W028
```

A complete description of the technical approach is provided in Appendix C.

PLSB

O3DG

RWF1   COY1

PLAI

SUTT

ALHA   TMSB

UCD1

CALD

SURV

RD20

MILL

ANDR

```
0    2000   4000        8000        12000
```

SCALE IN METERS

FRAME SURVEYING & MAPPING
609 A Street   Davis, CA   95616
(530) 756-8584 (TEL)   (530) 756-8201 (FAX)

1280-063 & 8905-001

APPENDIX A - NETWORK DIAGRAM
CITY OF DAVIS & RECLAMATION DISTRICT 2068
DEEP AQUIFER STUDY BENCHMARKS
JULY, 2004   SCALE: 1"= 4KM

Appendix B: New Station Descriptions

Station: RD2068

```
Lat:    38 24 54.178377
Long:  121 43 48.535595
```

The station is located about 9 miles south of Davis in Solano County.

To reach the station from the intersection of Interstate 80 and Mace Boulevard in Davis, go south on Mace Boulevard for about 3.9 mi to the intersection of Tremont Road, a side road right. Turn right and go west for 1.5 mi to the intersection of Bulkley Road, a side road left. Turn left and go south and southeast for 1.5 mi to the intersection of Maxwell Road. Continue south on Bulkley Road for 4.0 mi to a T-intersection at Midway Road. Turn right and go west for 0.4 mi to a gated gravel road on the left leading into the Reclamation District 2068 pumping facility. Turn left and go southerly for 0.1 mi and the station on the left.

The station is a 2" aluminum disk marked "FRAME SURVEYING & MAPPING LS5435 RD2068 2004" set in the south end of a concrete irrigation discharge structure at the west side of an irrigation pond. It is 28.5 ft east-southeast of the most southerly irrigation pump, 21 ft east of the pump structure, and 10 ft east of the centerline of a gravel road.

Station: RWF1

```
Lat:    38 35 09.998038
Long:  121 45 05.100575
```

The station is located in Yolo County about 1 mi north of Davis.

To reach the station from the intersection of State Highway 113 and County Road 29, go east on Road 29 for 0.8 mi to the intersection of Road 101A, a side road right that runs along the easterly side of the California Northern Railroad tracks. (Road 101A is also the northerly extension of F Street in Davis.) Turn right and go southeast on Road 101A for 0.3 mi and the station on the left.

The station is a 2" aluminum disk marked "YOLO COUNTY GEODETIC CONTROL RWF1 2004" set in the south end of a concrete headwall at the west end of a drainage structure beneath Road 101A. It is 0.8 ft north of the south end of the headwall, 47 ft west of the centerline of Road 101A, and 3.5 ft northeast of a 5" steel cable gate post.

Station: SUTTER

```
Lat:    38 33 53.289933
Long:  121 46 06.923002
```

The station is located in the northwest quadrant of the City of Davis.

To reach the station from the intersection of State Highway 113 and Covell Boulevard, go west on Covell Boulevard for 0.1 mi to the intersection of John Jones Road, a side road right. Turn right and go 0.3 mi north to the station on the left.

The station is a 2" aluminum disk marked "YOLO COUNTY GEODETIC CONTROL SUTTER 2004" set in the south end of a concrete headwall at the west end of a drainage structure beneath John Jones Road, which is the southerly extension of County Road 99D. It is 0.9 ft north of the south end of the headwall, 8.8 ft northeast of a storm drain manhole, 25.3 ft west of the centerline of John Jones Road, and 215 ft northwest of the northwest fence corner of the City of Davis Well No. 31 enclosure at No. 2074 John Jones Road.

Station: W028

```
Lat:    38 33 34
Long:  121 46 33
```

The station is located in the northwest quadrant of the City of Davis.

To reach the station from the intersection of State Highway 113 and Covell Boulevard, go west on Covell Boulevard for 0.6 mi to the intersection of Denali Drive, a side road left. Turn left and go south on Denali Drive for 0.1 mi to the intersection of Glacier Drive, a side road left. Turn left and go east for 0.2 mi to a 90° bend to the right and the station straight ahead.

The station is a 2" aluminum disk marked "YOLO COUNTY GEODETIC CONTROL W028 2004" set in the northwest corner of a 4' x 4' concrete pump base at City of Davis Well No. 28 at 2101 Glacier Drive in Davis. It is inside the locked well site; access is controlled by the City of Davis Public Works Department.

The station is 30.6 ft northeast of the southwest corner of the well site enclosure wall, 15.1 ft south of the north enclosure wall, and 18.6 ft east of the centerline of the entrance gate.

Appendix C: Technical Details

Stations RWF1, RD20, and SUTT

GPS Operations

Three of the new stations were positioned by means of GPS observations conducted during the period of July 5 through July 8, 2004. (See Appendix D for the observation schedule.) Each baseline in the network was observed at least twice, each observation occurring on a different day and with a time-of-day separation of at least 3 hours in accordance with NGS guidelines.

GPS baselines were processed using Trimble Geomatics Office v1.50, with a 15° elevation mask and precise ephemerides. The North American Datum of 1983 (NAD83) was used as the reference frame. All vectors processed with acceptable statistical results, indicating good data quality.   Star*Net Pro v6.0.25 was used for least-squares adjustment.

Baseline Ellipsoid Height Comparisons

Baseline groups – multiple observations of the same baseline – were compared to determine if the ellipsoid height differences were in agreement at the 2cm level. Of the 22 baseline groups encompassing vectors no longer than 10km (the maximum recommended under the guidelines), three groups exceeded 0.025m of ellipsoid height spread, the cutoff value inferred from the guidelines.

Two of the three noncompliant groups involve station SURVEYOR. The vector pair SURV to RD20 showed a spread of 0.041m, and the pair SURV to MILL showed 0.028. One of the baselines in each noncompliant pair was in close agreement with vectors from other stations, and the adjustment software appropriately discounted the effect of the outliers. Both outliers were produced by the same observing session, indicating a problem session. Inadequate satellite coverage during the session seems a likely culprit.

The other noncompliant group involved stations CALDWELL and RD2068.   This group comprises four independent sessions. When the obvious outlier is discarded, the height spread is reduced to 0.012m, well within the guidelines for acceptance.

Give the amount of redundancy in the network, the noncompliant groups were deemed to be of little importance, and were appropriately discounted by the adjustment software.

Control Station Subsidence Considerations

Because all of the network control stations are potentially subject to land subsidence, the adjustment process was designed to test the reliability of the published positions of the constraining stations. The first step was to perform a minimally-constrained adjustment, holding a single station, UCD1, fixed for latitude, longitude and ellipsoid height. The 2002.53 epoch values established during the 2002 Yolo County project were used for this position. *A priori* positions for all other control stations were updated or backdated to this epoch using NGS Horizontal Time Dependent Positioning (HTDP) software.

Once the integrity of the observation data had been demonstrated by the minimally-constrained adjustment, positional constraints were introduced one at a time in order to assess the effects of each new constraint upon the adjustment results. In addition to ensuring that each interim adjustment passed the standard chi square test, the process provided for careful monitoring of the GPS vector transformation parameters solved with each successive adjustment. This approach is based upon the assumption that the integrity of the GPS observations will be respected by legitimate constraints upon the adjustment, while invalid constraint values – in particular vertical values at stations that have been subject to land subsidence – will produce relatively large transformation parameters, unreasonably distorting the observation data.

The method yielded favorable results. The four solved parameters (scale factor and rotation about each of three axes) from the final adjustment are as follows:

```
Datum Transformations                                StdDev
Scale Factor 1.000000068342  :      -0.068342 PPM   0.1404 (Solved)
Rotation Around North Axis   :       0.068418 Sec   0.1135 (Solved)
Rotation Around East Axis    :      -0.204224 Sec   0.0500 (Solved)
Rotation Around Vert Axis    :       0.012423 Sec   0.0287 (Solved)
```

The largest rotation, approximately 0.2 arc-seconds about the east-west axis, would correspond to a vertical error of less than 2cm at the northerly and southerly ends of the project. This is consistent with the expected accuracy of the methods used.

The constraining values used in the final adjustment are given below. (Ellipsoid height values given for the CORS are those of the antenna L1 phase center.)

Station	Latitude	Longitude	EH	Constraints (Meters)		
				Lat	Long	EH
UCD1	38 32 10.44729	121 45 04.37739	0.305	FIXED	FIXED	FIXED
03DG	38 38 27.43690	121 45 39.59540	-6.780	0.005	0.005	0.005
ALHA	38 33 31.09757	121 42 26.68762	-18.130	0.005	0.005	0.005
CALD	38 27 33.51280	121 39 24.21307	-25.940	0.005	0.005	0.005
PLSB	38 41 06.12873	121 45 45.14024	-6.960	0.005	0.005	0.005
ANDR	38 23 12.17743	121 38 18.71969	-27.860	0.005	0.005	0.020
COY1	38 35 28.05097	121 41 31.83411	-22.410	0.005	0.005	0.010
PLAI	38 35 05.49717	121 48 11.62107	-11.170	0.005	0.005	0.020
TMSB	38 34 14.79956	121 32 57.13392	-14.644	0.005	0.005	0.030
MILL	38 23 41.27809	121 47 10.32780	-20.910	0.040	0.020	0.020
SURV	38 27 08.54320	121 44 56.17168	-18.130	0.030	0.020	0.020

With the exception of UCD1, which was held fixed in three dimensions, the minimum constraining value employed was 0.005m (5mm) in order to allow the adjustment software to operate effectively. This level of constraint is at or below the noise level of the technology, and for practical purposes may be considered equivalent to a fixed constraint. The larger constraining values shown were the result of the iterative adjustment process described earlier.

Final adjusted coordinates and residuals are provided below. The adjusted values are expressed in California Coordinate System of 1983 (CCS83) coordinates and NAD83 ellipsoid height. All values are in meters except those of the standard residuals, which are expressed as ratios.

Station	Component	Adj Coordinate	Residual	StdErr	StdRes
03DG	N	608178.9535	0.0051	0.0050	1.0
	E	2020806.8712	0.0018	0.0050	0.4
	EH	-6.7835	-0.0035	0.0050	0.7
ALHA	N	599055.3136	-0.0039	0.0050	0.8
	E	2025501.2849	-0.0106	0.0050	2.1
	EH	-18.1270	0.0030	0.0050	0.6
ANDR	N	579993.3109	0.0050	0.0050	1.0
	E	2031580.6138	-0.0037	0.0050	0.7
	EH	-27.8824	-0.0224	0.0200	1.1
CALD	N	588045.1044	0.0056	0.0050	1.1
	E	2029960.7241	-0.0127	0.0050	2.5
	EH	-25.9410	-0.0010	0.0050	0.2
COY1	N	602665.8245	0.0036	0.0050	0.7
	E	2026817.1095	-0.0011	0.0050	0.2
	EH	-22.4139	-0.0039	0.0100	0.4
MILL	N	580849.8002	0.0401	0.0400	1.0
	E	2018676.9884	-0.0161	0.0200	0.8
	EH	-20.8883	0.0217	0.0200	1.1
PLAI	N	601943.5385	-0.0018	0.0050	0.4
	E	2017143.9654	-0.0077	0.0050	1.5
	EH	-11.1458	0.0242	0.0200	1.2
PLSB	N	613071.7002	0.0083	0.0050	1.7
	E	2020659.9996	0.0044	0.0050	0.9
	EH	-6.9586	0.0014	0.0050	0.3
SURV	N	587248.8994	0.0264	0.0300	0.9
	E	2021914.7823	-0.0156	0.0200	0.8
	EH	-18.1140	0.0160	0.0200	0.8
TMSB	N	600459.2120	0.0078	0.0050	1.6
	E	2039283.7432	0.0042	0.0050	0.8
	EH	-14.5923	0.0517	0.0300	1.7

Final adjusted geodetic positions (latitude, longitude and ellipsoid height) are as follows:

Station	Latitude	Longitude	EH
03DG	38 38 27.437066	121 45 39.595325	-6.7835
ALHA	38 33 31.097445	121 42 26.688057	-18.1270
ANDR	38 23 12.177594	121 38 18.719843	-27.8824
CALD	38 27 33.512982	121 39 24.213592	-25.9410
COY1	38 35 28.051087	121 41 31.834155	-22.4139
MILL	38 23 41.279392	121 47 10.328459	-20.8883
PLAI	38 35 05.497113	121 48 11.621387	-11.1458
PLSB	38 41 06.128997	121 45 45.140057	-6.9586
SURV	38 27 08.544059	121 44 56.172321	-18.1140
TMSB	38 34 14.799813	121 32 57.133743	-14.5923
UCD1	38 32 10.447290	121 45 04.377390	0.3050
RWF1	38 35 09.998038	121 45 05.100575	-16.4247
RD20	38 24 54.178377	121 43 48.535595	-19.2319
SUTT	38 33 53.289933	121 46 06.923002	-16.2851

These results reveal that the adjusted positions of stations MILLAR and SURVEYOR do not fit the HTDP-modified published horizontal values at the 4cm and 3cm levels, respectively, nor the published ellipsoid heights at the 2cm level. While the ellipsoid height differences are within the error budget, the horizontal differences are unexpectedly large. The results of the 2002 reobservation of the Delta Project have not been published, so an independent check upon these positions is not yet available. (It is important to note that even the sessions that produced noncompliant height comparisons returned very small horizontal residuals.) Given the emphasis upon vertical results for these projects, the horizontal anomalies at these two stations are not considered significant in light of the acceptable results at the remaining control stations.

Once final ellipsoid heights were determined, NAVD88 orthometric height separation values were calculated in order to derive NAVD88 elevations at the three new stations. Although continental geoid modeling is becoming more accurate, even the most recent model (GEIOD03) is too generalized to account for short-wavelength geoid undulations in the project area. For this reason, the separation between the NAD83 ellipsoid and the NAVD88 datum surface at each of the new GPS stations was interpolated on a plane defined by three surrounding control stations. The separation values used to define each plane were derived by subtracting the published NAVD88 height from the published ellipsoid height. The interpolated separation value was then subtracted from the adjusted ellipsoid height to produce the NAVD88 elevation at the station. (See Figure 1, below.)
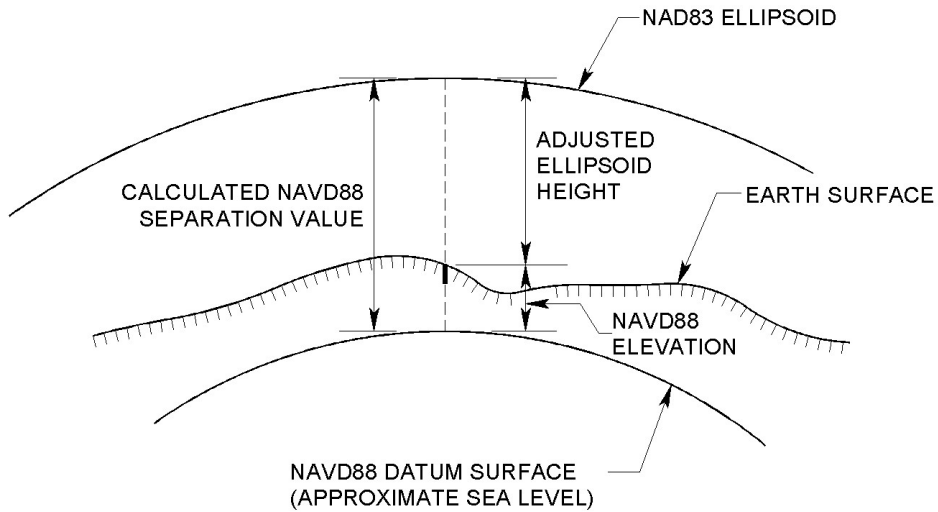
Figure 1.

Final adjusted NAVD88 and ellipsoid heights are shown below. The GEOID03 (modeled) heights calculated by the adjustment software and the NGS published heights are provided for comparison. (Note that adjusted values are shown with more significant digits than is warranted by the methods used to produce them. The additional digits are provided only to indicate the degree of conformity with published values.)

Station	NAVD88 Final	NAVD88 GEOID03	NAVD88 Published	Ellipsoid Adjusted	Ellipsoid Published
03DG	**24.087**	24.0576	24.09	-6.7835	-6.78
ALHA	**12.973**	12.9665	12.97	-18.1270	-18.13
ANDR	**3.648**	3.7007	3.67	-27.8824	-27.86
CALD	**5.419**	5.4442	5.42	-25.9410	-25.94
COY1	**8.546**	8.5350	8.55	-22.4139	-22.41
MILL	**10.912**	10.9296	10.89	-20.8883	-20.91
PLAI	**19.984**	19.9706	19.96	-11.1458	-11.17
PLSB	**23.707**			-6.960	-0.001
SURV	**13.466**	13.4646	13.45	-18.1140	-18.13
TMSB	**16.273**			-14.644	-0.052
UCD1	**31.545**	31.5527	31.55	0.3050	0.305
RWF1	**14.635**	14.6237		-16.4247	
RD20	**12.409**	12.4576		-19.2319	
SUTT	**14.875**	14.8716		-16.2851	

Station W028

Due to the proximity of W028 to SUTT (approximately 1km), geodetic leveling was chosen as the most cost-effective method of establishing a current NAVD88 elevation at the W028. The leveling was conducted on [date] using a Leica [level model] and Leica fiberglass barcode staff model [rod model]. [Fill in details when available.]

Appendix D: GPS Observation Schedule

City of Davis & RD 2068
Deep Aquifer Bench Mark Project

RD2068 SESSIONS

Day 1, July 5 (JD 187)

RECEIVER	SESSION 1	SESSION 2	SESSION 3
Start: (UTC)	**12:15pm** (1915)	**1:30pm** (2030)	**2:45pm** (2145)
Stop: (UTC)	**1:00pm** (2000)	**2:15pm** (2115)	**3:30pm** (2230)
ANDY	**RD2068**	**RD2068**	**RD2068**
JIM	**SURVEYOR**	**SURVEYOR**	**ANDREW**
DON	**MILLAR**	**CALDWELL**	**CALDWELL**

Day 2, July 6 (JD 188)

RECEIVER	SESSION 1	SESSION 2	SESSION 3
Start: (UTC)	**8:30am** (1530)	**9:45am** (1645)	**11:00am** (1800)
Stop: (UTC)	**9:15am** (1615)	**10:30am** (1730)	**11:45am** (1845)
ANDY	**RD2068**	**RD2068**	**RD2068**
JIM	**SURVEYOR**	**SURVEYOR**	**ANDREW**
DON	**MILLAR**	**CALDWELL**	**CALDWELL**

SUTTER AND RWF1 SESSIONS

Day 3, July 7 (JD 189)

RECEIVER	SESSION 1	SESSION 2	SESSION 3	SESSION 4
Start: (UTC)	**8:00am** (1500)	**9:30am** (1630)	**11:45am** (1845)	**1:15pm** (2015)
Stop: (UTC)	**8:45am** (1545)	**10:15am** (1715)	**12:30pm** (1930)	**2:00pm** 2100)
ANDY	**RWF1**	**RWF1**	**RWF1**	**RWF1**
JIM	**SUTTER**	**SUTTER**	**03 DG**	**03 DG**
DON	**PLAI**	**ALHA**	**COY**	**PLAI**
CORS	**UCD1**	**UCD1**	**UCD1**	**UCD1**

Day 4, July 8 (JD 190)

RECEIVER	SESSION 1	SESSION 2	SESSION 3	SESSION 4
Start: (UTC)	**8:00am** (1500)	**9:30am** (1630)	**11:45am** (1845)	**1:15pm** (2015)
Stop: (UTC)	**8:45am** (1545)	**10:15am** (1715)	**12:30pm** (1930)	**2:00pm** 2100)
ANDY	**RWF1**	**RWF1**	**RWF1**	**RWF1**
JIM	**03 DG**	**03 DG**	**SUTTER**	**SUTTER**
DON	**COY**	**PLAI**	**PLAI**	**ALHA**
CORS	**UCD1**	**UCD1**	**UCD1**	**UCD1**

Appendix E: Baseline Height Comparisons

```
BL      STA1  STA2     ? Ht.     Length      Start Date / Time

B7      SURV  RD20    -1.150    4456.040    04/07/05, 19:05:15.000
B16     SURV  RD20    -1.109    4456.041    04/07/06, 15:00:00.000
****   Height spread = 0.041

B32     UCD1  RD20   -19.517   13577.312    04/07/06, 15:00:00.000
B34     UCD1  RD20   -19.552   13577.319    04/07/05, 19:05:15.000
****   Height spread = 0.035

B9      CALD  RD20     6.692    8076.574    04/07/05, 20:27:30.000
B10     CALD  RD20     6.714    8076.578    04/07/05, 21:45:00.000
B11     CALD  RD20     6.726    8076.572    04/07/06, 16:43:00.000
B12     CALD  RD20     6.717    8076.575    04/07/06, 17:58:45.000
****   Height spread = 0.034

B2      SURV  MILL    -2.793    7171.714    04/07/05, 19:03:45.000
B6      SURV  MILL    -2.765    7171.713    04/07/06, 15:19:15.000
****   Height spread = 0.028

B63     UCD1  TMSB   -14.913   18021.658    04/07/06, 00:06:45.000
B64     TMSB  UCD1    14.894   18021.655    04/07/07, 00:00:00.000
B68     UCD1  TMSB   -14.910   18021.657    04/07/05, 00:06:45.000
B69     TMSB  UCD1    14.921   18021.657    04/07/06, 00:00:00.000
B110    TMSB  UCD1    14.908   18021.657    04/07/07, 00:06:45.000
B118    UCD1  TMSB   -14.901   18021.660    04/07/08, 00:00:00.000
B119    TMSB  UCD1    14.915   18021.658    04/07/08, 00:06:45.000
****   Height spread = 0.027

B13     RD20  MILL    -1.672    5387.433    04/07/05, 19:05:15.000
B14     RD20  MILL    -1.647    5387.444    04/07/06, 15:19:15.000
****   Height spread = 0.025

B20     UCD1  CALD   -26.232   11868.614    04/07/05, 20:27:30.000
B21     UCD1  CALD   -26.241   11868.612    04/07/05, 21:45:00.000
B22     UCD1  CALD   -26.245   11868.614    04/07/06, 16:43:00.000
B24     UCD1  CALD   -26.255   11868.612    04/07/06, 17:58:45.000
****   Height spread = 0.023

B35     UCD1  PLSB    -7.281   16547.460    04/07/06, 00:06:45.000
B36     PLSB  UCD1     7.262   16547.460    04/07/06, 00:00:00.000
B62     PLSB  UCD1     7.267   16547.461    04/07/07, 00:00:00.000
B105    PLSB  UCD1     7.277   16547.458    04/07/07, 00:06:45.000
B107    UCD1  PLSB    -7.264   16547.459    04/07/08, 00:00:00.000
B108    PLSB  UCD1     7.280   16547.458    04/07/08, 00:06:45.000
       Height spread = 0.019

B40     RWF1  PLAI     5.288    4516.430    04/07/07, 14:38:15.000
B42     RWF1  PLAI     5.289    4516.427    04/07/07, 19:56:30.000
B90     RWF1  PLAI     5.272    4516.419    04/07/08, 18:43:30.000
B96     RWF1  PLAI     5.274    4516.423    04/07/08, 16:08:30.000
       Height spread = 0.017

B85     UCD1  COY1   -22.720    7975.271    04/07/07, 18:05:45.000
B94     UCD1  COY1   -22.735    7975.272    04/07/08, 14:34:45.000
       Height spread = 0.015
```

Combined Project Report – City of Davis & RD 2068 Deep Aquifer Benchmarks Projects

```
BL      STA1   STA2    ? Ht.      Length       Start Date / Time

B82     UCD1   PLAI    -11.457    7048.894     04/07/07, 14:35:45.000
B88     UCD1   PLAI    -11.447    7048.886     04/07/07, 19:56:30.000
B91     UCD1   PLAI    -11.447    7048.886     04/07/08, 18:43:30.000
B97     UCD1   PLAI    -11.462    7048.888     04/07/08, 16:08:30.000
        Height spread = 0.015


B26     UCD1   MILL    -21.180    15994.248    04/07/05, 19:03:45.000
B27     UCD1   MILL    -21.165    15994.236    04/07/06, 15:19:15.000
        Height spread = 0.015


B18     UCD1   ANDR    -28.187    19292.428    04/07/06, 17:52:45.000
B29     UCD1   ANDR    -28.173    19292.431    04/07/05, 21:41:45.000
        Height spread = 0.014


B45     03DG   COY1    -15.642    8156.247     04/07/07, 18:28:30.000
B48     03DG   COY1    -15.629    8156.255     04/07/08, 14:34:45.000
        Height spread = 0.013


B66     RWF1   TMSB     1.827     17702.418    04/07/07, 14:38:15.000
B117    TMSB   RWF1    -1.815     17702.418    04/07/08, 14:31:00.000
        Height spread = 0.012


B41     RWF1   COY1    -5.994     5191.310     04/07/07, 18:05:45.000
B93     RWF1   COY1    -5.983     5191.311     04/07/08, 14:34:45.000
        Height spread = 0.011


B43     ALHA   SUTT     1.846     5375.751     04/07/07, 16:12:30.000
B120    ALHA   SUTT     1.837     5375.744     04/07/08, 20:01:15.000
        Height spread = 0.009


B76     UCD1   SUTT    -16.590    3514.302     04/07/07, 14:34:45.000
B100    UCD1   SUTT    -16.599    3514.301     04/07/08, 18:30:30.000
        Height spread = 0.009


B73     ALHA   UCD1    18.437     4556.956     04/07/07, 16:12:30.000
B123    ALHA   UCD1    18.428     4556.954     04/07/08, 20:01:15.000
        Height spread = 0.009


B1      CALD   SURV     7.830     8085.422     04/07/05, 20:27:30.000
B5      CALD   SURV     7.821     8085.426     04/07/06, 16:43:00.000
        Height spread = 0.009


B60     RD20   TMSB     4.594     23409.848    04/07/06, 15:00:00.000
B61     RD20   TMSB     4.603     23409.854    04/07/05, 19:05:15.000
        Height spread = 0.009


B37     RWF1   ALHA    -1.708     4899.493     04/07/07, 16:12:30.000
B122    RWF1   ALHA    -1.700     4899.498     04/07/08, 20:01:15.000
        Height spread = 0.008


B8      ANDR   RD20     8.650     8598.627     04/07/06, 17:52:45.000
B15     ANDR   RD20     8.643     8598.630     04/07/05, 21:41:45.000
        Height spread = 0.007


B38     RWF1   SUTT     0.140     2798.956     04/07/07, 14:38:15.000
B99     RWF1   SUTT     0.146     2798.956     04/07/08, 18:30:30.000
        Height spread = 0.006
```

```
BL No. STA1  STA2    ? Ht.     Length    Start Date / Time

B65    PLSB  RWF1   -9.451    11024.147   04/07/07, 14:38:15.000
B106   PLSB  RWF1   -9.457    11024.148   04/07/08, 14:31:00.000
       Height spread = 0.006

B67    RWF1  UCD1   16.728     5536.548   04/07/07, 14:38:15.000
B109   RWF1  UCD1   16.734     5536.551   04/07/08, 14:31:00.000
       Height spread = 0.006

B3     CALD  ANDR   -1.935     8213.250   04/07/06, 17:58:45.000
B4     CALD  ANDR   -1.929     8213.249   04/07/05, 21:45:00.000
       Height spread = 0.006

B77    PLSB  03DG    0.174     4895.228   04/07/07, 18:28:30.000
B101   PLSB  03DG    0.179     4895.228   04/07/08, 14:31:15.000
       Height spread = 0.005

B70    TMSB  PLSB    7.633    22493.797   04/07/06, 00:00:00.000
B104   PLSB  TMSB   -7.630    22493.793   04/07/07, 00:00:00.000
B116   TMSB  PLSB    7.635    22493.794   04/07/08, 00:00:00.000
       Height spread = 0.005

B79    03DG  UCD1    7.099    11655.849   04/07/07, 18:28:30.000
B103   UCD1  03DG   -7.104    11655.855   04/07/08, 14:31:15.000
       Height spread = 0.005

B39    03DG  RWF1   -9.633     6145.077   04/07/07, 18:28:30.000
B102   RWF1  03DG    9.629     6145.077   04/07/08, 14:31:15.000
       Height spread = 0.004

B46    03DG  PLAI   -4.354     7232.045   04/07/07, 19:56:30.000
B49    03DG  PLAI   -4.351     7232.050   04/07/08, 16:08:30.000
       Height spread = 0.003

B17    UCD1  SURV  -18.433     9311.304   04/07/05, 18:45:45.000
B30    UCD1  SURV  -18.430     9311.296   04/07/06, 14:52:45.000
       Height spread = 0.003


B44    SUTT  PLAI    5.138     3750.820   04/07/07, 14:35:45.000
B47    SUTT  PLAI    5.138     3750.816   04/07/08, 18:43:30.000
       Height spread = 0.000
```

```
              Appendix F:  GPS Vector Residual Summary (Meters)
                        (Sorted by 3D Residual Length)


From       To            N        E       Up       2D       3D    Length  VectID
SURV       RD20      -0.003   -0.000    0.035    0.003    0.035     4456  21
UCD1       RD20       0.004    0.004    0.027    0.006    0.028    13577  62
SURV       MILL       0.003   -0.000    0.027    0.003    0.027     7172  82
CALD       RD20      -0.002    0.002    0.026    0.003    0.026     8077  78
UCD1       SURV       0.002   -0.003    0.023    0.004    0.023     9311  60
RD20       MILL      -0.006   -0.006    0.021    0.008    0.022     5387  85
UCD1       SURV      -0.006   -0.000    0.020    0.006    0.020     9311  29
RD20       TMSB       0.002    0.001    0.019    0.002    0.019    23410  49
TMSB       UCD1      -0.001   -0.003    0.018    0.003    0.018    18022  27
PLSB       UCD1       0.003   -0.004    0.017    0.005    0.018    16547  53
UCD1       PLSB      -0.001    0.002   -0.015    0.003    0.015    16547  37
UCD1       CALD      -0.006   -0.000    0.013    0.006    0.014    11869  20
03DG       COY1      -0.004    0.001    0.013    0.004    0.014     8156  6
UCD1       MILL      -0.007   -0.001   -0.012    0.007    0.014    15994  34
PLSB       UCD1       0.003   -0.003    0.012    0.005    0.013    16547  4
CALD       SURV      -0.000    0.003    0.012    0.003    0.012     8085  43
RWF1       PLAI      -0.000   -0.006    0.010    0.006    0.012     4516  68
UCD1       TMSB      -0.000   -0.003   -0.011    0.003    0.011    18022  36
ANDR       RD20       0.004    0.002    0.010    0.004    0.011     8599  83
UCD1       CALD      -0.001    0.001   -0.011    0.002    0.011    11869  17
RD20       TMSB      -0.001   -0.003    0.010    0.003    0.010    23410  84
RWF1       COY1       0.001   -0.000   -0.010    0.001    0.010     5191  66
UCD1       ANDR      -0.001   -0.000    0.010    0.001    0.010    19292  30
ALHA       UCD1       0.002   -0.002    0.009    0.003    0.010     4557  16
TMSB       UCD1       0.004   -0.002   -0.009    0.004    0.010    18022  52
RWF1       ALHA      -0.006    0.002    0.007    0.006    0.009     4899  11
UCD1       PLAI      -0.001    0.001    0.009    0.001    0.009     7049  75
CALD       RD20      -0.004    0.000   -0.008    0.004    0.009     8077  42
UCD1       RD20      -0.003   -0.001   -0.008    0.004    0.009    13577  31
TMSB       RWF1      -0.001    0.002   -0.008    0.002    0.009    17702  54
RWF1       PLAI       0.004    0.001   -0.008    0.004    0.008     4516  26
UCD1       SUTT       0.004   -0.002    0.007    0.005    0.008     3514  71
RWF1       PLAI       0.000   -0.003    0.008    0.003    0.008     4516  69
UCD1       COY1       0.002    0.002   -0.008    0.002    0.008     7975  39
RWF1       PLAI      -0.001    0.005   -0.006    0.005    0.008     4516  23
RD20       MILL      -0.004    0.005   -0.004    0.007    0.008     5387  50
CALD       RD20       0.007   -0.000    0.004    0.007    0.008     8077  81
ALHA       SUTT      -0.001   -0.002    0.007    0.002    0.008     5376  15
SURV       RD20      -0.003   -0.004   -0.005    0.005    0.008     4456  47
UCD1       MILL       0.006   -0.002    0.004    0.006    0.007    15994  64
UCD1       PLAI      -0.005    0.004    0.004    0.006    0.007     7049  38
UCD1       COY1       0.000    0.001    0.007    0.001    0.007     7975  72
PLSB       03DG      -0.003   -0.001    0.006    0.004    0.007     4895  1
RWF1       UCD1      -0.001   -0.000    0.007    0.001    0.007     5537  24
UCD1       PLAI       0.001   -0.001   -0.007    0.001    0.007     7049  40
CALD       SURV      -0.006   -0.001    0.003    0.006    0.007     8085  79
RWF1       03DG       0.000    0.001    0.006    0.001    0.007     6145  67
CALD       ANDR       0.001   -0.003   -0.006    0.003    0.006     8213  80
RWF1       ALHA       0.004    0.005   -0.002    0.006    0.006     4899  14
UCD1       PLAI       0.002    0.000   -0.006    0.002    0.006     7049  74
UCD1       03DG      -0.003    0.003    0.005    0.004    0.006    11656  73
03DG       PLAI      -0.006    0.000   -0.000    0.006    0.006     7232  8
UCD1       ANDR       0.003    0.001   -0.004    0.003    0.005    19292  61
UCD1       CALD       0.000    0.005   -0.001    0.005    0.005    11869  18
```

```
ALHA      SUTT      -0.001    0.005   -0.002    0.005    0.005    5376   12
CALD      RD20       0.005   -0.002    0.001    0.005    0.005    8077   45
PLSB      RWF1       0.000    0.001   -0.005    0.001    0.005   11024    2
TMSB      UCD1       0.002   -0.001    0.004    0.002    0.005   18022   28
UCD1      CALD       0.001    0.004    0.003    0.004    0.005   11869   19
RWF1      TMSB      -0.001   -0.001   -0.004    0.001    0.005   17702   22
03DG      COY1       0.002   -0.004    0.000    0.004    0.004    8156   77
RWF1      COY1      -0.004    0.001    0.001    0.004    0.004    5191   25
SURV      MILL      -0.001    0.004   -0.001    0.004    0.004    7172   46
RWF1      SUTT      -0.002    0.002    0.003    0.003    0.004    2799   10
PLSB      03DG      -0.004   -0.002    0.001    0.004    0.004    4895   57
UCD1      SUTT       0.003   -0.001   -0.002    0.004    0.004    3514   35
ANDR      RD20       0.001   -0.003    0.003    0.003    0.004    8599   48
TMSB      UCD1       0.002   -0.000   -0.003    0.002    0.004   18022   56
RWF1      SUTT       0.000   -0.001   -0.003    0.001    0.004    2799   65
SUTT      PLAI       0.003   -0.001    0.001    0.004    0.004    3751   86
03DG      UCD1      -0.004    0.000    0.000    0.004    0.004   11656    9
CALD      ANDR       0.003    0.000    0.001    0.003    0.003    8213   44
UCD1      PLSB      -0.003    0.001    0.002    0.003    0.003   16547   33
03DG      RWF1       0.000    0.001   -0.003    0.001    0.003    6145    7
PLSB      TMSB      -0.001    0.001   -0.003    0.002    0.003   22494    3
03DG      PLAI      -0.001    0.001   -0.003    0.002    0.003    7232   76
TMSB      PLSB       0.000   -0.001   -0.002    0.001    0.003   22494   55
RWF1      UCD1       0.001   -0.001    0.001    0.002    0.002    5537   70
TMSB      PLSB      -0.002    0.001    0.000    0.002    0.002   22494   51
PLSB      UCD1       0.001    0.001   -0.001    0.002    0.002   16547   59
ALHA      UCD1      -0.001    0.002    0.000    0.002    0.002    4557   13
UCD1      TMSB       0.000    0.001   -0.002    0.001    0.002   18022   63
PLSB      UCD1       0.001    0.000    0.001    0.001    0.002   16547    5
SUTT      PLAI      -0.000    0.001    0.001    0.001    0.001    3751   41
UCD1      TMSB      -0.001   -0.000    0.001    0.001    0.001   18022   32
PLSB      RWF1       0.000    0.001    0.001    0.001    0.001   11024   58
```